A STUDY OF THE USE OF COD, COD BY-PRODUCTS AND CRUSTACEAN BY-PRODUCTS FOR SURIMI AND SURIMI-BASED PRODUCTS: PART 1 - RAW MATERIAL ASSESSMENT

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ABSTRACT

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Laboratory and pilot scale production of surimi primarily from trawler cod (Gadus morhua) and to a lesser extent from other groundfish species were carried out in this study. The Bibun pilot line was used in the pilot scale production. The surimi produced was tested and its quality assessed. This study indicated that with increased post-mortem age of stored fish in ice for extended periods of time, there was a decline in ductility of surimi. Also the gel strength (torsion shear stress) was not influenced by freshness of raw material and most of the variation in gel strength can be explained on the basis of surimi moisture content. However, ductility (torsion shear strain) was influenced by freshness of raw material and to a lesser extent by moisture content of surimi. This study indicated that surimi can be produced from trawler cod and grade two quality trawler cod fillets with a slight odour can be produced into odourless, white surimi of reasonable quality. In the laboratory scale study, surimi yields as high as 48% (80% moisture content) of head-on-gutted cod weight was obtained using cod fillets compared to 29% maximum yield obtained in the pilot scale study. The surimi yield produced from "split" trawler cod on the pilot line was excellent (34% of head-on-gutted weight). This yield was twice as good as that normally obtained commercially from trap cod fillets at Terra Nova Fisheries. Cod frames and flounder frames showed much promise in this study as suitable raw material for the production of acceptable quality surimi. Jellied flounder was found unsuitable for surimi production. Pilot line runs with haddock and redfish produced good quality surimi.

RÉSUMÉ

Chandra, C.V. August 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products: Part I - Raw Material Assessment Can. Ind. Rep. Fish Aquat. Sci. 177: 46p.

De la morue (Gadus morhua) et d'autres espèces de poisson de fond pêchées au chalut ont été transformées en surimi en laboratoire et sur une chaîne de fabrication pilote Bibun. Le surimi obtenu a fait l'objet d'essais et de vérifications de la qualité. La présente étude a révélé que la mise en glace du poisson pour une période prolongée se traduit par une baisse de la ductilité du surimi. De plus, la résistance du gel (tension de cisaillement par torsion) ne dépend pas de la fraîcheur de la matière première et les changements que subit la résistance du gel sont dus en grande partie à la teneur en humidité du surimi. Toutefois, la ductilité (déformation en cisaillement par torsion) dépend de la fraîcheur de la matière première et, dans une moindre mesure, de la teneur en humidité du surimi. L'étude a aussi révélé qu'on peut obtenir du surimi de bonne qualité à partir de morue pêchée au chalut et que des filets de morue de deuxième qualité capturée au chalut,

même s'ils ont une légère odeur, peuvent être transformés en surimi blanc, sans odeur et de qualité acceptable. Dans l'étude en laboratoire, on a obtenu un rendement de 48 % (teneur en humidité = 80 %) en poids avec des filets de morue éviscérée et non étêtée contre 29 % au maximum au cour de l'étude pilote. On a obtenu un rendement excellent avec de la morue fendue pêchée au chalut et transformée en surimi sur la chaîne de fabrication pilote (34 % du poids de la morue éviscérée et non étêtée). Ce rendement est deux fois supérieur à celui généralement obtenu avec de la morue pêchée à la trappe et transformée à la Terra Nova Fisheries. Les os de morue et de poissons plats se sont révélés une source possible de matière première pour la production de surimi de qualité acceptable tandis que les poissons plats en gelée ne conviennent pas à la production de surimi. D'autres essais effectués avec de l'aiglegin et du sébaste ont donné du surimi de bonne qualité.

PREFACE

A contract was awarded to a research team from the Newfoundland and Labrador Institute of Fisheries and Marine Technology (The Marine Institute) and Memorial University to study the potential of selected Canadian Atlantic fish species and shellfish processing wastes to produce surimi and shellfish flavours. Research to develop methodology for rapidly determining the potential of raw materials to produce surimi was initiated, objective laboratory techniques for evaluating the quality of surimi were established, a pilot line for producing surimi was installed and surimi was produced from cod and other groundfish. Some biochemical indices of cod were analysed under various conditions of storage and methods were established which may assist as predictors of surimi potential from cod and possibly other species. Crab process wastes and scallop process wastes were analysed for their contents of flavour-active components. Methods of concentrating flavours were identified.

Three separate publications from this contract were issued. Correct citation for these are:

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Voigt, M.N. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part 111 - Shellfish Flavour Extraction Studies.

The opinions and interpretations expressed in the report are those of the author, and do not necessarily reflect those of the Department of Fisheries and Oceans.

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INTRODUCTION

During the past decade, there has been an ever growing world-wide interest in surimi and surimi-based products. Surimi is a Japanese word for mechanically deboned fish flesh that has been washed in water and mixed with cryoprotectants. Its unique properties make it very attractive to food processors and food technologists. Surimi has long term frozen storability (12-14 months) without major protein degradation. Because of its bland flavour and its malleability it can be flavoured with natural and artificial additives to produce a great variety of products, ranging from seafood to confectionery. Its low fat and calorie content and its high protein value make surimi-based products attractive to health conscious consumers of the developed nations.

About 90% of the surimi produced in the world is made from Alaskan pollock and there is a reasonable amount of data available on surimi made from this species. However, very little research has been done on surimi processed from cod. The only Canadian surimi and surimi-based products plant is in Clarenville, Newfoundland (Terra Nova Fisheries). They have found that trap cod serves as a good raw material for the manufacture of surimi and surimi-based products. However, little is known about factors that may affect the quality of surimi: for example, fish harvesting methods, area and season of catch, post-mortem history, handling practices and use of cod by-products.

Due to the late starting date of the project (September 1985) resulting from budgetary delays and the late arrival of the Bibun surimi production

line (February 1986), it was possible to carry out only limited studies. Work completed by the Marine Institute from September 1985 to March 1986 was mainly concentrated on producing surimi from trawler cod. This was the only cod available during the period of study. There are no reports in the literature of previous work on trawler cod.

Surimi was also produced using cod frames, flounder frames, jellied flounder fillets, redfish and haddock as raw material. The surimi produced was then assessed for its quality by conducting certain standard tests.

A preliminary run on the pilot production line was also conducted to assess yield losses suffered during the dewatering process using the screw press.

MATERIALS AND METHODS

Atlantic cod (**Gadus morhua**) used in this project were all market sized 51 - 64 cm (20"-25") crux length trawler cod harvested from November 1985 to March 1986 in the 3K NAFO area.

Other species investigated for their suitability in surimi production included redfish, flounder and haddock. Species of fish during storage studies were kept in ice in a chilled room at a temperature of 2°C-4°C.

LABORATORY SCALE SURIMI

Laboratory scale surimi was produced by deboning fillets in a Baader 694 deboner (drum size of 3 mm or 5 mm bore) and washing it in cool tap water (5°C-7°C). The amount of water used for the washing was twice the

weight of the minced flesh, which was washed for 10 minutes and decanted through a stainless steel China cap strainer (1 mm bore). A total of three 10 minute washings were completed. The third washing was carried out in 0.14% NaCl. The washed minced fish flesh was then put in a heavy grade, closely woven muslin bag and dewatered with a Carver press at 5,000 p.s.i. for 5 minutes. Cryoprotectants (4% sorbitol, 4% sucrose and 0.3% sodium polyphosphate) were mixed with the dewatered flesh in a Hobart mixer for about 3 minutes.

PILOT SCALE SURIMI

Essentially, the pilot scale surimi produced from the Bibun surimi line followed steps similar to that described for the laboratory scale surimi production, except the whole process was automatic and had only two washings (each of 15 minutes duration). The second washing was carried out in 0.14% saline. Another difference was that the pilot line had a refiner which separated the impurities (like bone, scales, dark meat, etc.) from the washed fish flesh. The resulting refined fish flesh was dewatered through a screw press. See Fig. 13 for the flow chart of the surimi manufacturing process using the Bibun pilot line. The dewatered fish flesh was then mixed with cryoprotectants (4% sucrose, 4% sorbitol, and 0.3% sodium polyphosphate) in a silent cutter for about 3 minutes to produce surimi.

In all laboratory and pilot scale surimi processed from cod fillets in the post-mortem age storage studies, 0.14% NaCl was used in the final washing of the minced flesh. In all other studies, (cod frames, "split"

cod, haddock, flounder and redfish), 0.3% NaCl was used instead, to promote dewatering. The surimi was subsequently analysed either in the unfrozen state or after freezing.

QUALITY TESTS ON RAW SURIMI

The following tests were conducted on the surimi. (All tests, unless otherwise stated, were carried out in triplicates and the average noted):

1) The moisture content was ascertained by noting the weight loss after placing 10 g of surimi in an oven at 105° for about 6 hours (until there was no further reduction of weight).
2) The lightness (whiteness) of surimi was measured by noting the "L" value with the Hunter-Gardner tristimulus colorimeter.
3) The pH was measured by adding 10 g of raw surimi to 100 ml of distilled water, blending it in a food processor and measuring the slurry with a pH meter.
4) The foreign element test (Suzuki 1981) was carried out by noting the number of foreign elements (such as scales, black or white membranes, etc.) in 10 g of raw surimi that has been spread out in 1 mm thickness. Only elements at or above 1 mm long were considered. They were scored according to the following 10 point scale.

TEST SCORE	NO. OF FOREIGN ELEMENTS
10	0
9	1 - 2
8	3 - 4
7	5 - 7
6	8 - 11
5	12 - 15
4	16 - 19
3	20 - 25
2	26 - 30
1	Over 31

QUALITY TESTS ON COOKED SURIMI

Surimi test specimens were prepared by mixing, under vacuum, 2% salt to about 3 kg of sliced, tempered (-2°C) surimi in a Stephan Cutter until the temperature rose to 5°C. The resulting paste was stuffed into two types of stainless steel tubes (i.d. 1.25 cm x 17.5 cm and 1.9 cm x 17.5 cm) and sausage casings (i.d. 3.0 cm x 30 cm). They were cooked at three different temperatures (viz. 40°C, 60°C and 90°C). The 40°C specimens received a second heat treatment at 90°C. The resulting cooked surimi specimens were cooled. Their heat induced gel properties were analyzed within 24 hours of their preparation.

1) The lightness (whiteness) of surimi was measured by noting the "L" value with the Hunter-Gardner Tristimulus colorimeter.

2) Torsion failure tests were carried out as described by Montejano et al. (1983). The cylindrical surimi specimens were ground to a dumbbell shape with a length of 2.87 cm, end diameter of 1.9 cm and middle diameter of 1 cm. Using a modified Brookfield Viscometer, the stress and strain at failure of the surimi specimens were calculated using appropriate equations (Hamann 1983). The torsion shear stress (gel strength) is the maximum force required to bring the dumbbell shaped cooked surimi to breaking point. Torsion shear strain (ductility) is the degree of deformation that occurs in bringing the dumbbell shaped specimen to failure.

3) The compression (punch) tests were carried out on the cooked cylindrical surimi specimens (3 cm diameter by 2.87 cm length) using the Ottawa texturometer. Energy, work and deformation at failure of the specimen when the surface was pierced by a 5 mm (diameter) ball probe was calculated using appropriate equations (N.S. MacDonald & G. Churchill, Unpublished).

4) The Ottawa texturometer was used to obtain the hardness value of the cooked cylindrical surimi specimens having a diameter of 1.25 cm and length of 2.87 cms. Using appropriate equations the hardness values for the first and second compression were calculated (Lanier et al. 1984). Hardness is the force per gram of surimi specimen required to compress a 1.25 cm end diameter cylindrical specimen to 0.75 cm. It is expressed in Newtons per gram.

5) The fold tests were conducted to measure elasticity using cooked surimi (kamaboko) slices of 3 mm thickness and having a diameter of 30 mm,

after it had been cooled to room temperature. The slices of the samples were first folded in halves, then quarters. The cracks or breaks that occurred after the folding were noted and scored as follows:

SCORE	RESULT OF FOLDING
5	Does not crack after folding in quarters.
4	Does not crack after folding in halves.
3	Cracks gradually when folding in half.
2	Cracks immediately when folding in half.
1	Breaks or crumples by finger pressure.

Five fold tests were completed for each sample and the average score noted.

RESULTS AND DISCUSSION

PROPERTIES OF SURIMI FROM ATLANTIC COD

Certain properties of surimi prepared from 28 lots of Atlantic cod are summarized in Tables 1 and 2, according to the process material used. It is indicated whether the surimi was prepared by laboratory or pilot operation.

The pH of laboratory scale surimi tended to be somewhat lower than that of pilot scale surimi when fillets were processed (Table 1). However, the

average pH of surimi prepared from two lots of "split"[1] cod with the pilot line was similar to that of laboratory scale surimi from fillets. The pH of laboratory scale surimi from fillets of trap cod in another study has been observed to be indicative of the quality of the raw material (Haard and Warren 1986).

The white colour of cooked surimi from both laboratory scale and pilot scale were similar. The colour of surimi from "split"[1] cod was a little greyer than surimi obtained from fillets, while the colour of surimi from frames was greyer than that obtained from split fish (Table 1). In another study the colour scores for laboratory scale surimi from trap cod, also cooked at 90°C, were somewhat lower (73.2 ± 1.4)(Haard and Warren 1986) than for trawler cod (77.7 ± 1.5).

Laboratory scale surimi contained more foreign elements than pilot scale surimi (Table 1). This was due to the smaller bore size of material used in the dewatering process, and also the lack of refiner with the laboratory scale method. As would be expected, surimi prepared from split cod (pilot) or frames (lab) contained more foreign elements than surimi prepared from fillets.

The average moisture content of laboratory scale surimi was lower (79.4%) than that of pilot surimi (80.8%) prepared from fillets by 1.4% (Table 2). Preliminary studies with frames and split cod produce a surimi product having a moisture content less than 80%. The average moisture content of surimi obtained from pre-rigor trap cod was 76%, while that for

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[1]In this report, when a fish is termed as "split", it refers to headless, gutted fish that has been cut ventrally to the dorsal edge, leaving the whole backbone intact, unlike split saltfish where the soundbone has been removed.

surimi obtained from trap fish held on ice for up to 3 weeks was 78% (Haard and Warren 1986).

Laboratory scale surimi from fillets had better elasticity and ductility than surimi from the pilot line as shown by the fold test and torsion failure strain (Table 2). However, preliminary studies with split cod indicate an excellent product, with respect to elasticity and ductility, can be obtained with the pilot line. The lower gel strength (stress) of surimi prepared from fillets with the pilot line compared to laboratory scale, may be partly due to its higher average moisture content. Comparison of moisture content and torsion gel strength of 24 samples indicate moisture content is inversely related to the gel strength of pilot scale surimi but not laboratory scale surimi (Fig. 1). On the other hand, it is difficult to explain the lower ductility (strain) of surimi prepared by the pilot line compared to that prepared by laboratory scale on the basis of moisture content, since regression analysis of the data indicated ductility is directly related to moisture content (Fig. 2). A torsion failure strain of 2.28 ± .34 was noted for surimi prepared from Atlantic croaker and sand trout and cooked at 90°C (Montejano et al. 1984). Accordingly, it appears that surimi from Atlantic cod, even when held on ice for more than two weeks prior to processing, is more ductile than that from croaker/sand trout. The data for the fold test are consistent with this conclusion. However, the average gel strength of surimi from Atlantic cod is considerably lower than that reported for croaker/sand trout surimi cooked at 90°C (76.61 ± 10.1, Montejano et al. 1984).

During the production of surimi, it was observed that Grade 2 quality

trawler cod that had a slight odour (usually after the post-mortem age of about 8 days), lost its odour and produced reasonable quality surimi. This has great significance, as this may be one means of utilizing Grade 2 quality cod, for which there is limited demand commercially.

The quality of both laboratory and pilot scale surimi produced from trawler cod compared favourably with the surimi quality produced commercially from trap cod at the plant in Clarenville by Terra Nova Fisheries (Appendix D). Details of test results conducted on pilot and laboratory scale surimi are summarized in Appendices A-E. Generally the colour, the gel strength and ductility of the surimi produced from trawler cod, (and from haddock and redfish) were as good as, if not better than, that of the commercially produced trap cod surimi. It must be stressed that as only one sample from Terra Nova Fisheries was available for testing, it can only be used as an indicator. More samples will be required to lend strength to the comparison. Nevertheless, it can still be used as a reference point to compare experimentally produced surimi with that used to produce commercial crab legs.

PROPERTIES OF SURIMI FROM OTHER SPECIES

The properties of surimi prepared from redfish (fillet and split), flounder frame and haddock fillet with the pilot line are summarized in Tables 3 and 4. Redfish and haddock meat yield a surimi having excellent ductility (strain) and elasticity (fold)(Table 4). However, the preliminary results for flounder frame meat, like that for cod frame meat

(Table 2) indicate a product having poor ductility and elasticity. It would be useful, in future studies, to determine whether proteolysis of actomyosin is indicated in surimi from frame meat. Such may be the case due to the expected higher content of proteolytic enzymes, from viscera, blood and bacteria in frame meat. Because of the excellent ductility of surimi from split cod or fillet, it may be possible to blend surimi from frames with the former and still have a product which meets a particular user's specifications.

One attempt was made to produce surimi from heavily jellied flounder (90% moisture content) using the pilot line. It was soon discovered that it was not possible to produce any surimi, since the entire contents of the minced and washed flounder flesh oozed out of the screw press and went down the drain as waste.

INFLUENCE OF COOK TEMPERATURE ON SURIMI FROM ATLANTIC COD

Surimi from cod was cooked at three temperatures, 40°C-90°C, 60°C and 90°C to form a gel. Cooking temperature did not appreciably influence the whiteness and mechanical properties of the resulting gel (Table 5). The results of this study differ from those reported by others for croaker/sand trout surimi, where it was observed that gels formed at 40°C-90°C have a lower gel strength and higher ductility than those prepared at 90°C (Montejano et al. 1984). Moreover, cooking croaker surimi at 60°C results in a dramatic loss in gel strength and ductility, perhaps by activation of alkaline protease. This so called "himadori" phenomenon does not appear to be of importance in cod surimi.

INFLUENCE OF POSTHARVEST ICE TIME ON PROPERTIES OF COD SURIMI

The influence of ice time on the properties of cod surimi is illustrated in Figs. 3-11. For each property, regression analysis of data for surimi prepared from fillets by both laboratory and pilot scale is shown to indicate trends.

The pH of surimi prepared by the pilot line, but not by laboratory scale, increased with ice storage time of the raw material (Fig. 3). Other studies with surimi prepared from trap cod fillets indicated results similar to those shown in this study for surimi from trawler cod prepared with the pilot line, and inverse relationships between fold test and surimi pH (Warren & Haard 1986). The reason why laboratory fillet surimi pH did not show increase in pH level with increased ice storage time in the present study is not clear. Future studies should be directed to determine whether pH control during surimi preparation with the pilot line affects gel strength and other properties of the surimi.

The Lightness value of raw surimi showed considerable variation but regression analysis did not indicate striking trends with respect to postharvest storage time (Fig. 4). However, the Lightness of cooked surimi tended to decrease with increasing the age of the raw material (Fig. 5).

For laboratory scale surimi from fillets, foreign element scores decreased (ie. number of foreign elements increased) with the storage life of the raw material; whereas for pilot scale surimi, foreign element scores remained consistently high (Fig. 6). The higher foreign element score of pilot scale surimi would appear to be due to the larger bore size in the material used during dewatering and the addition of the refining step, in

the former process.

The moisture content of surimi tended to decrease with postharvest storage of the raw material (Fig. 8). This trend was more pronounced with laboratory scale batches than with pilot scale batches of surimi. As shown earlier with laboratory surimi prepared from trap cod, the moisture content of surimi from cod held on ice tends to increase during the first week of ice storage and thereafter tends to decrease (Haard & Warren, 1986). The pattern of surimi moisture appears to parallel the transition of the raw material flesh consistency from firm to soft (first week) to fibrous (after first week).

The mechanical properties of gels formed from cod surimi at 90°C cook temperature are summarized in Figs. 9-11. All three tests (fold, gel strength and gel ductility) indicated that the mechanical properties of gels from pilot scale surimi deteriorated more rapidly, with respect to postharvest storage time, than did gels from laboratory scale surimi.

RELATIONSHIP BETWEEN MECHANICAL PROPERTIES OF SURIMI

For 87 samples, analysis by regression indicated that gel ductility correlates with fold test better than gel strength as measured by torsion failure (Fig. 12, Table 6). Deformation, measured by the compression test, and hardness also appear to correlate reasonably well with fold test result (Table 6). The fairly low regression coefficients probably reflect the fact that the fold test does not discriminate between excellent and good quality surimi, each of which will yield a fold test of "5"; whereas a measure such as torsion strain does discriminate between such samples. It

is recommended that future studies employ the torsion failure test since this gives a measure of gel strength, which may be important in certain end products, as well as ductility, which appears to be a more sensitive indicator of gel pliability than the fold test.

For 10 laboratory and 11 pilot cod surimi samples, regression analysis indicated that gel strength (torsion shear stress) was not influenced by the freshness of raw material and most of the variation in gel strength could be explained on the basis of surimi moisture content. Ductility (torsion shear strain), however, was influenced by freshness of raw material and to a lesser extent by moisture content of surimi (Table 7). Other unknown variables appeared to contribute to variations in ductility observed for these sets of surimi samples prepared from cod fillets.

SURIMI YIELD STUDIES FROM ATLANTIC COD

The yield of surimi, prepared from fillets, was much greater in the laboratory scale process than it was in the pilot scale process (Table 1). The poorer yield with the pilot surimi line appears to be due to losses of finer particles during dewatering. However, fairly good yields were obtained from "split" cod with the pilot line. The yield of surimi (without cryoprotectants) from trap cod was approximately 65% of fillet meat (Haard and Warren, 1986). Assuming a skin-on fillet yield of 45% from eviscerated, (ie. dressed) cod, this would indicate an approximate surimi yield (with cryoprotectants) of 34% from eviscerated trap fish. The yield of commercially produced surimi by Terra Nova Fisheries varied from 35% to 45% of trap cod fillet weight. (Ho, personal communications). This

translated from 16% to 20% of eviscerated cod weights which was lower than the average yield of 23.3% obtained in the pilot scale surimi produced from trawler cod fillets in the present study. The somewhat lower yield of commercially produced surimi from trap cod is consistent with the higher content of myofibrillar protein in winter fish (Haard 1986).

The yield of surimi tended to decrease with postharvest age of the raw material, more so for pilot scale surimi than for laboratory scale surimi (Fig.7). Further pilot scale studies with cod less than 6 days old may indicate marked improvement in yield. It is possible that very fresh fish, when processed with the pilot line, may have greatly improved surimi yields.

A comparison of surimi yield studies between a pilot scale and laboratory scale production is shown in Table 8. As can be seen, under controlled laboratory scale surimi production, it was possible to achieve a yield of 47.6% of eviscerated cod weight from full napped fillets and a yield of 6.8% of eviscerated cod from cod frames with the backbone around the kidney region removed. A surimi yield of 34.4% of eviscerated cod was obtained on the pilot line using "split" cod. During this particular process, as shown in Table 9, 17.5% of eviscerated cod weight was lost as minced waste; 3.7% lost as refiner waste; 5.7% lost as screw press waste; 1.1% lost as surimi still stuck inside the screw press and 22.4% lost due to the cod's head which was not used in the surimi process. Therefore, the unaccounted loss (due to soluble proteins, fats, and bits and pieces of fish flesh stuck to the pilot line machinery) was about 15.2% of eviscerated cod weight. The pilot scale surimi performance worked out to

be about 63% of the laboratory scale surimi production.

During one particular production of pilot scale surimi, the final washing was inadvertently carried out in one tenth the required salt concentration. A yield loss as much as 12.7% of eviscerated cod weight was noted compared to a corresponding similar sample. This underlies the great importance of having the appropriate concentration of salt (NaCl) in the final washing process in order to achieve good surimi yields. In this study all surimi yields have been expressed at 80% moisture content as a percentage of eviscerated (ie. Head-on, Gutted) cod weight, unless otherwise stated.

CONCLUSION

This preliminary study, although limited in the number of samples examined, does indicate and help establish that good quality surimi can be produced from trawler cod. Generally, the surimi quality is related to the post-mortem age of the cod. Analysis of the cod surimi data indicated that ductility (torsion shear strain) was influenced by freshness of raw material and, to a lesser extent, by the moisture content of surimi. Gel strength (torsion shear stress) was not influenced by freshness of raw material but was influenced by moisture content.

It was also observed that Grade 2 quality trawler cod with a slight odour can be produced into odourless surimi of reasonable quality.

Cod frames and flounder frames, being treated as waste product, are a potential source of raw material for producing second grade surimi.

Jellied flounder was found to be unsuitable for surimi production.

Haddock produced excellent quality surimi and compared well with that made from cod.

Redfish, although being a much more oily fish than cod or haddock, did produce a good quality surimi. Refinements to the process to remove the excess oil during the washing process should be investigated. This species could become a good source of raw material for surimi production.

Surimi produced from "split" cod on the pilot line was promising. Its quality was good and yield excellent. The yield, in fact, was about twice as good as that normally obtained commercially from trap cod fillet at Terra Nova Fisheries. Admittedly, further refinements need to be sought, but the present study does indicate that "split" cod would be much cheaper and easier to use than cod fillet as a raw material in the production of surimi.

There was quite a difference in surimi yields between the laboratory and pilot scale production. The laboratory scale does indicate the possible maximum potential yield attainable. Improvements in the pilot line in terms of wastage encountered during the processing warrant further investigation. Possibly, a finer screen in the screw press, or screening or centifuging press waste water and recycling the fines through the press, could help improve the yield.

ACKNOWLEDGEMENTS

I am particularly grateful to Dr. Norman F. Haard of Memorial University of Newfoundland for his advice given in the production of laboratory scale surimi and his invaluable help given in the analyses of the surimi data obtained.

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Table 1. Properties of Surimi from Atlantic Cod Harvested by Trawl, January-March						
Process	Age (days)[1]	N[2]	pH	Lightness[3]	Foreign Elements	Yield[4]
Lab/Fillet	2-14	10	7.10 ± 0.14	77.7 ± 1.5	7.0 ± 1.3	43.7 ± 2.1
Pilot/Fillet	6-15	13	7.37 ± 0.24	77.8 ± 2.8	9.1 ± 0.3	23.3 ± 4.1
Lab/Frame	7-14	3	7.16 ± 0.08	69.2 ± 0.8	3.0 ± 1.0	5.1 ± 1.8
Pilot/Split	8-13	2	7.08 ± 0.12	72.9 ± 0.2	8.0 ± 0	39.0 ± 5.2

[1] Range of postharvest ice time for eviscerated fish.

[2] Number of batches of surimi prepared by indicated process.

[3] "L" value (0 = theoretical black; 93.7 = white reference) for gel prepared from surimi cooked at 90°C. Data also available for raw surimi and surimi cooked at 40°C and 60°C

[4] Yield based on recovery of surimi (80% moisture) from eviscerated fish.

Table 2. Properties of Surimi from Atlantic Cod Harvested by Trawl, January-March						
Process Age (days)[1]		N[2]	Moisture (%)	Fold Test[3]	Stress (KPa)[4]	Strain[5]
Lab/Fillet	2-14	10	79.4 ± .9	5.0 ± 0	28.4 ± 6.5	2.65 ± .45
Pilot/Fillet	6-15	13	80.8 ± 2.2	3.0 ± 2	9.6 ± 4.5	2.21 ± .73
Lab/Frame	7-14	3	78.8 ± 2.2	2.0 ± 2	10.3 ± 3.5	1.88 ± .45
Pilot/Split	8-13	2	79.3 ± 4.7	5.0 ± 0	37.3 ± 24.5	2.48 ± .13

[1] Range of postharvest ice time for eviscerated fish.

[2] Number of batches of surimi prepared by indicated process.

[3] Fold test for gel cooked at 90°C. Similar results obtained for gels prepared at 40°C and 60°C.

[4] Gel strength measured by Torsion Failure test. Data for gels cooked at 40°C and 60°C are similar.

[5] Ductility measured by Torsion Failure. Data for gels cooked at 40°C and 60°C are similar.

Table 3. Properties of Surimi Processed by Pilot Line from Species other than Atlantic Cod.						
Fish	Process	Age (Days)[1]	pH	Lightness[2]	Foreign Elements	Yield[3]
Redfish	split	5	7.4	75.5	8	n.d
Redfish	fillet	7	7.5	80.8	9	n.d
Flounder	frame	11	7.5	70.0	9	10.0
Flounder	frame	12	7.5	70.0	9	12.0
Haddock	fillet	7	7.1	76.3	9	26.4[4]

[1] Estimated time on ice of trawl caught fish.

[2] "L" values for gel cooked at 90°C. Similar results obtained for gels cooked at 40°C or 60°C.

[3] Yield based on recovery of surimi (80% moisture) from eviscerated fish.

[4] Value based on assumed fillet yield of 50%. Yield of surimi from fillets was 52.7%.

Table 4. Properties of Surimi Processed by Pilot Line from Species other than Atlantic Cod.

Fish	Process	Age (days)[1]	Moisture (%)	Fold Test[2]	Stress (KPa)[3]	Strain[4]
Redfish	split	5	80.0	5	27.2	2.91
Redfish	fillet	7	80.4	5	18.1	3.91
Flounder	frame	11	77.1	1	n.d.	n.d.
Flounder	frame	12	77.1	1	29.4	1.81
Haddock	fillet	7	76.1	5	66.0	3.89

[1] Estimed time on ice of trawl caught fish.

[2] Fold test for gel cooked at 90°C. Same results obtained for gels cooked at 40°C or 60°C.

[3] Gel strength measured by Torsion failure test. Data for gels cooked at 40°C and 60°C similar with exception of flounder surimi which had approximately half the gel strength when cooked at the lower temperatures.

[4] Ductility measured by Torsion failure. Similar results observed for gels cooked at 40°C and 60°C.

Table 5. Influence of Cooking Temperature on Properties of Gel Formed from Atlantic Cod Surimi[1].

Property	Units	N[2]	Cook Temperature 40°C	60°C	90°C
Lightness	L	24	76.7 ± 4.2	75.8 ± 3.8	76.6 ± 3.4
Fold Test	-	27	3.96 ± 1.63	3.89 ± 1.72	4.07 ± 1.69
Torsion Failure					
Gel Strength (Shear stress)	KPa	25	24.1 ± 15.1	21.6 ± 16.3	24.6 ± 18.0
Ductility (Shear strain)	-	25	2.38 ± .72	2.38 ± .72	2.39 ± .57
Compression					
Deformation	cm	8	.97 ± .21	.96 ± .25	.96 ± .25
Energy	J	8	.012± .007	.010 ± .006	.009 ± .004
Work	J	8	.006± .004	.005 ± .003	.005 ± .002
Hardness					
Hardness 1	N/g	6	1.17 ± .77	1.13 ± .75	1.09 ± .77
Resilience (Hardness 2/Hardness 1)	-	6	.91	.87	.87

[1] Data for surimi prepared from Atlantic cod using fillet, split cod or frarmes by either laboratory or pilot scale process. ± value is standard deviation.

[2] N is number of surimi samples analyzed.

Table 6. Relation between Fold Test and other Mechanical Properties		
Independent Variable	$(R^2)^1$	N
Torsion strain	.45	87
Torsion stress	.19	87
Torsion (stress x strain)	.21	87
Torsion (strain/stress)	.04	87
Compression Deformation	.47	17
Compression Energy	.12	17
Compression Work	.11	17
Hardness #1	.39	17
Hardness #2	.41	17
Torsion stress	.11	17
Torsion Strain	.45	17

1 R^2 is coefficient of determination for linear regression analysis for N lots of surimi with fold test as dependent variable.

Table 7. Dependence of Torsion Failure on Water Content of Atlantic Cod Surimi and Freshness of Raw Material.

Dependent Variable	Independent Variable(s)	$(R^2)^1$	N
Torsion strain	Postharvest ice time (a)	0.25	10 (Lab scale)
	Surimi water content (b)	0.10	10
	(a) + (b)	0.36	10
	Postharvest ice time (a)	0.17	11 (Pilot)
	Surimi water content (b)	0.06	11
	(a) + (b)	0.24	11
Torsion Stress	Postharvest ice time (a)	0.0	10 (Lab scale)
	Surimi water content (b)	0.84	10
	(a) + (b)	0.84	10
	Postharvest ice time (a)	0.0	11 (Pilot)
	Surimi water content (b)	0.82	11
	(a) + (b)	0.82	11

1 R^2 is coefficient of determination for linear regression analysis of N lots of surimi with indicated dependent and independent variables. Values for (a) + (b) are multiple linear regression analysis. The analyses indicate the gel strength (Torsion shear stress) is not influenced by freshness of raw material and most of the variation in gel strength can be explained on the basis of surimi moisture content. However, ductility (Torsion shear strain) is influenced by freshness of raw material and to a lesser extent by moisture content of the surimi. Other variables, not known at this time, appear to contribute to the variation in ductility observed for these sets of samples. Samples analyzed were lab scale (N = 10) and pilot scale (N = 11) surimi prepared from fillets.

Table 8. Comparison of Surimi Yields in a Pilot and Laboratory Scale Production (1).	
Lab scale surimi yield from cod fillet (7 days old) Process Date: January 14, 1986	47.6%
Lab scale surimi yield from cod frames (7 days old) Process Date: January 14, 1986	6.8%
Pilot scale surimi yield from "split" cod (4 days old) Process Date: April 10, 1986	34.4%

(1) Surimi yields expressed as a percentage of dressed cod weight and corrected to 80% moisture content.

Table 9. Breakdown of Yield Losses in a Pilot Scale Surimi Production from "Split" Cod.

Sample: "Split" cod, post-mortem age of 4 days.
Process Date: April 10, 1986.

Point of Loss	Percent Loss of Dressed Weight (80% Moisture)
Fish head	22.4
Mincer waste (skin & bones)	17.5
Refiner waste	3.7
Screw press waste	5.7
Surimi stuck to screw press	1.1
Surimi yield	34.4
Unaccounted loss (soluble proteins, fats and flesh stuck to pilot line)	15.2

Fig. 1. GEL STRENGTH vs MOISTURE CONTENT

ATLANTIC COD SURIMI

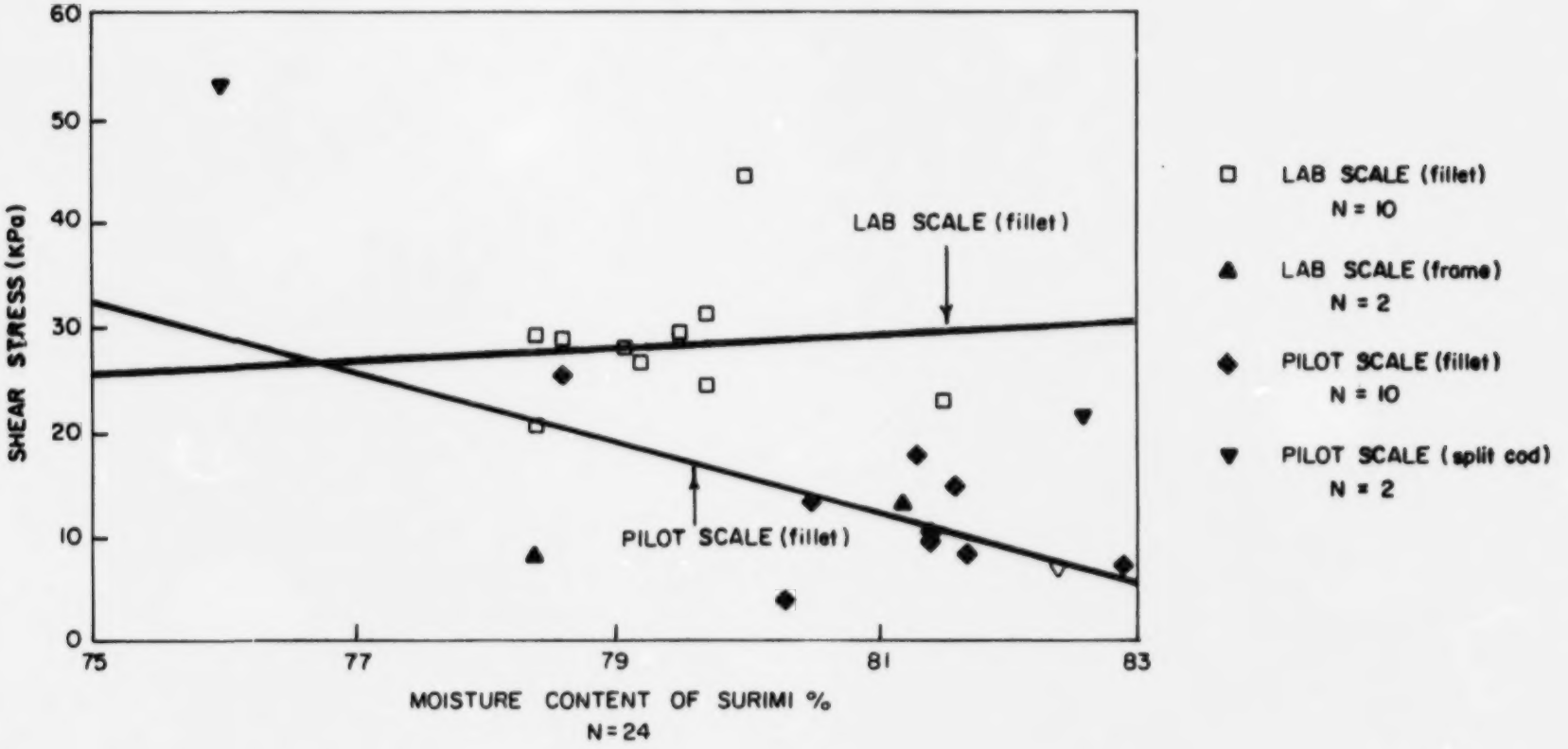
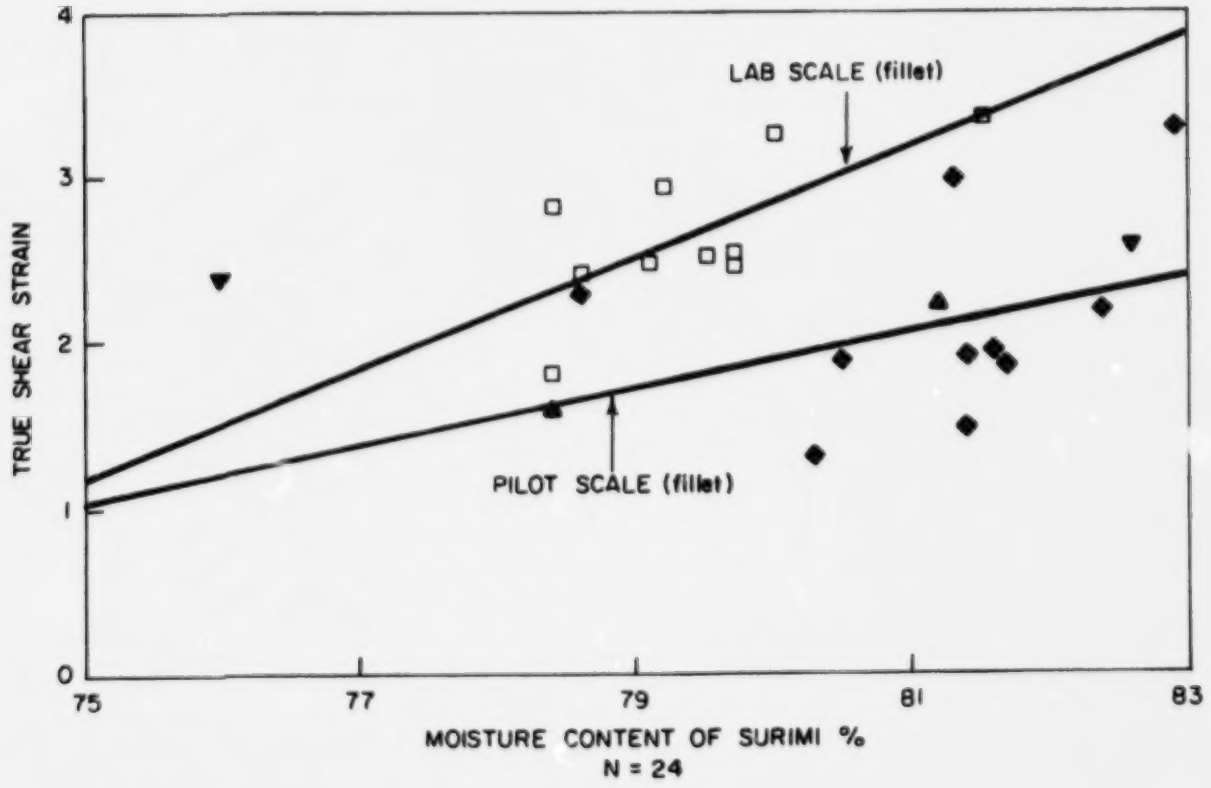


Fig. 2.

DUCTILITY vs MOISTURE CONTENT

ATLANTIC COD SURIMI



□ LAB SCALE (fillet)
N = 10

▲ LAB SCALE (frame)
N = 2

◆ PILOT SCALE (fillet)
N = 10

▼ PILOT SCALE (split cod)
N = 2

Fig. 3

pH OF SURIMI

ATLANTIC COD

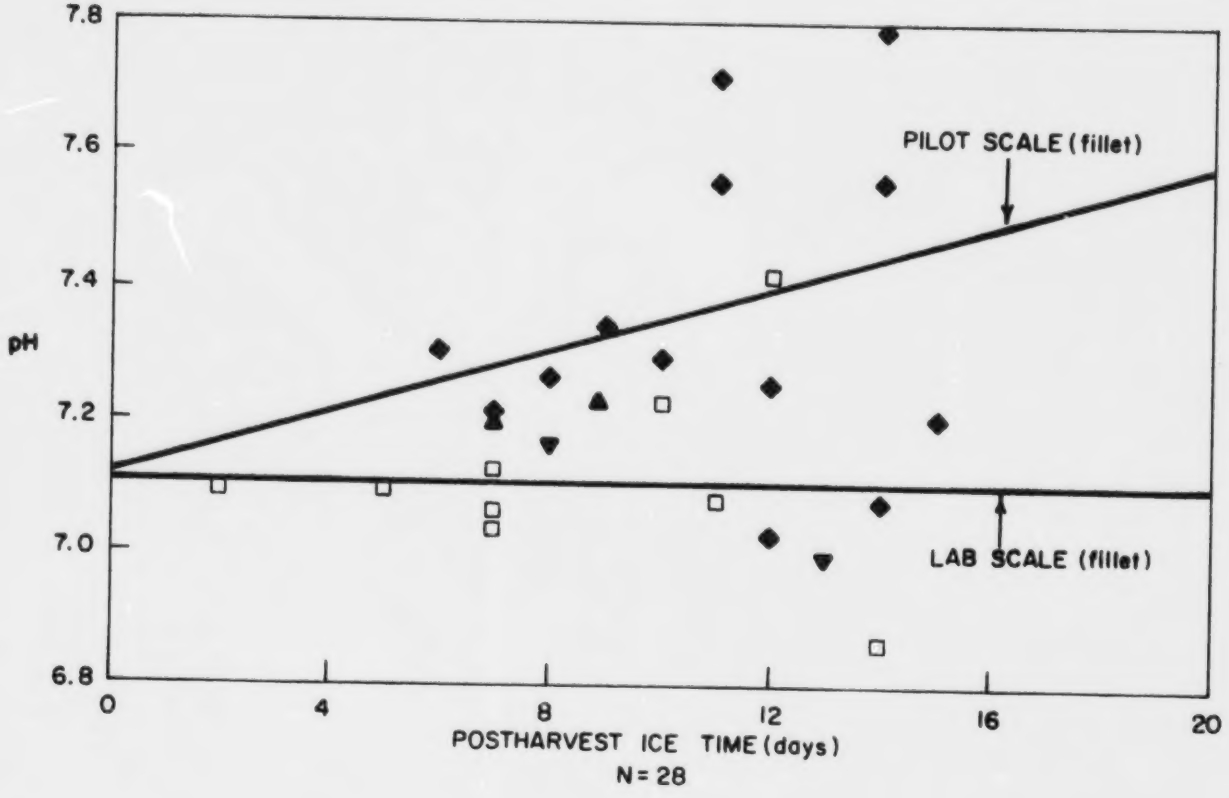
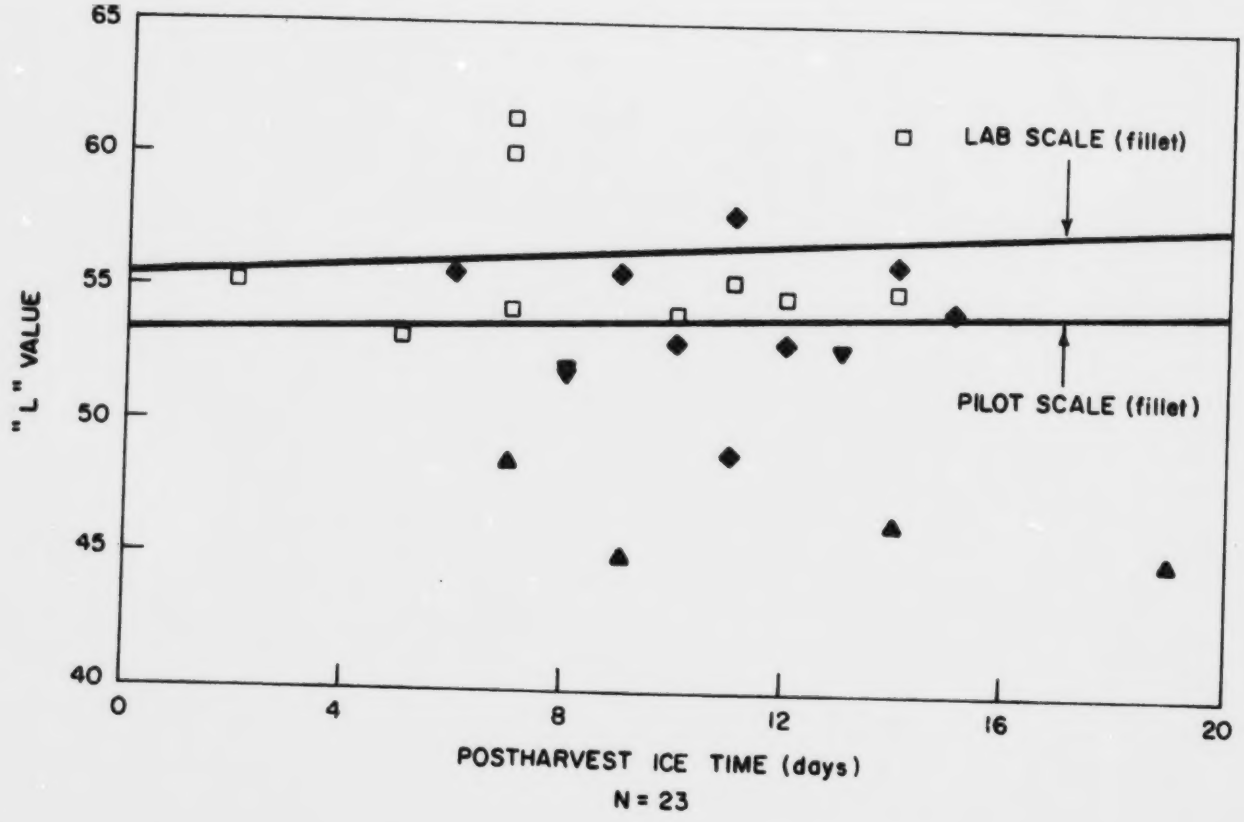


Fig. 4

LIGHTNESS OF RAW SURIMI

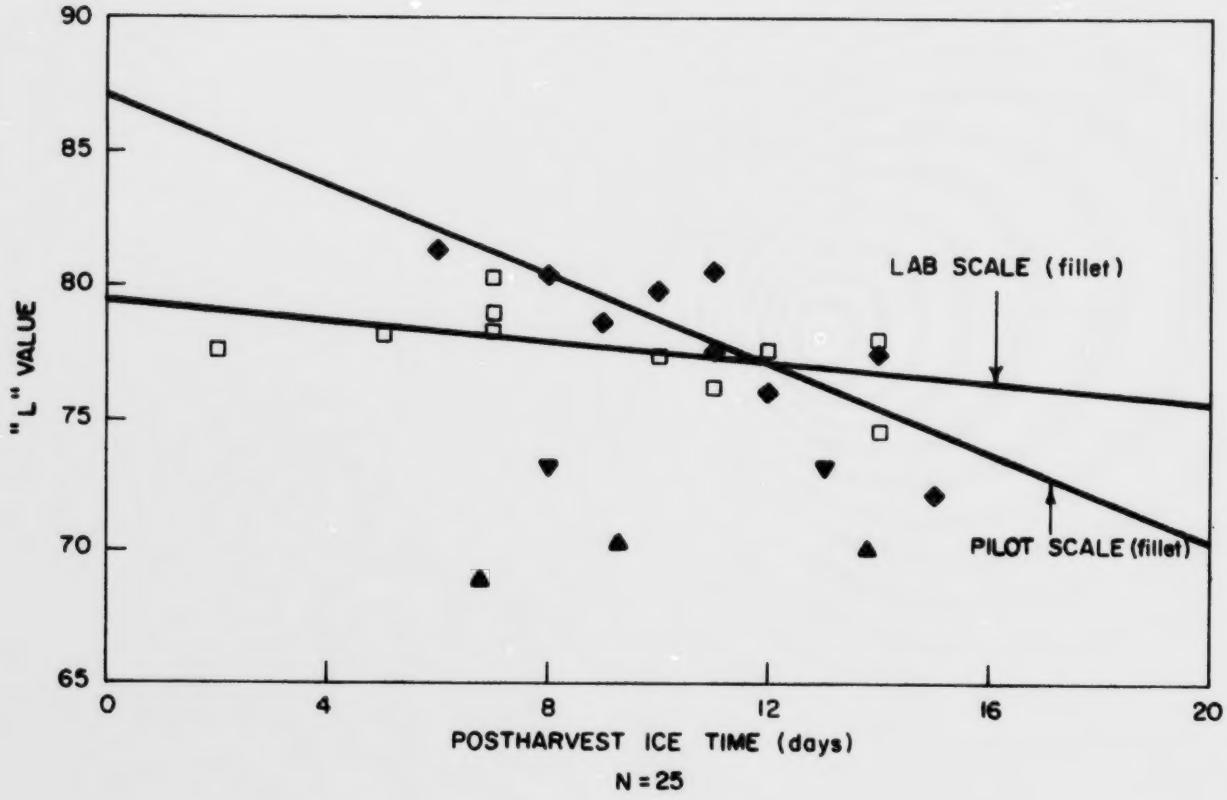
ATLANTIC COD



- □ LAB SCALE (fillet) AVERAGE 56.3 ± 3.1, N=10
- ▲ LAB SCALE (frame) AVERAGE = 46.5 ± 1.8, N=2
- ◆ PILOT SCALE (fillet) AVERAGE = 53.9 ± 2.6, N=9
- ▼ PILOT SCALE (split cod) AVERAGE = 50.9 ± 2.5, N=2

Fig. 5 LIGHTNESS OF COOKED (90°C) SURIMI

ATLANTIC COD



□ LAB SCALE (fillet)
AVERAGE = 77.7 ± 1.5 ; N = 10

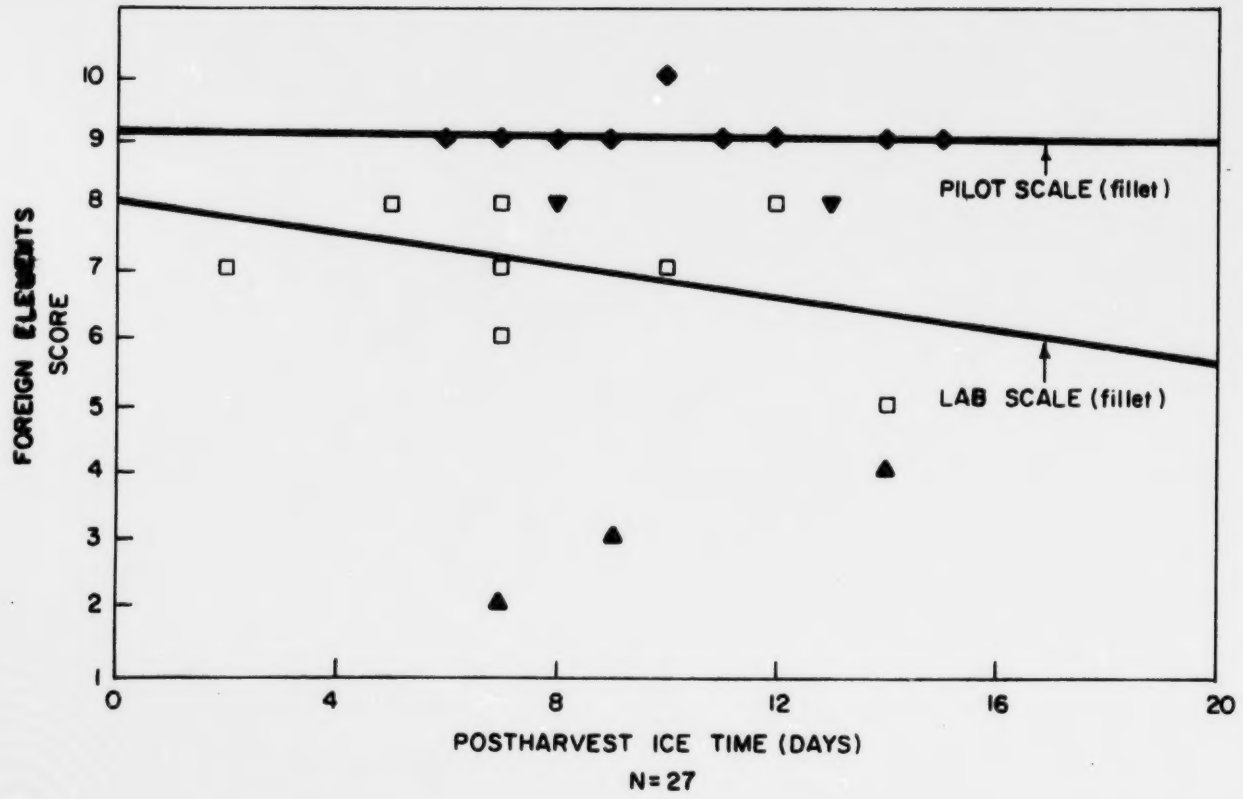
▲ LAB SCALE (frame)
AVERAGE = 69.2 ± 0.8 ; N = 3

◆ PILOT SCALE (fillet)
AVERAGE = 77.8 ± 2.8 ; N = 9

▼ PILOT SCALE (split cod)
AVERAGE = 72.9 ± 0.2 ; N = 3

Fig.6. **FOREIGN ELEMENTS IN SURIMI**

ATLANTIC COD



□ LAB SCALE (fillet)
AVERAGE = 7.0 ± 1.3, N=10

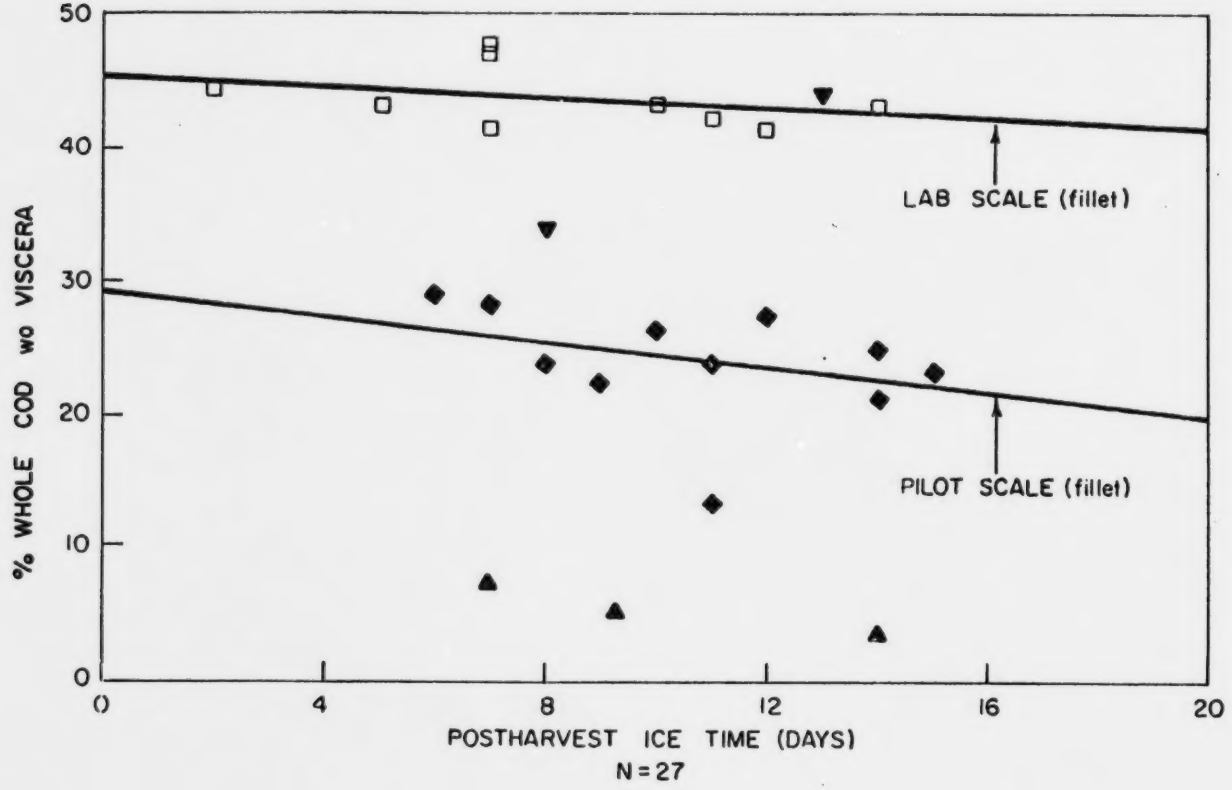
▲ LAB SCALE (frame)
AVERAGE = 3.0 ± 1.0, N=3

◆ PILOT SCALE (fillet)
AVERAGE = 9.1 ± 0.3, N=12

▼ PILOT SCALE (split cod)
AVERAGE = 8.0 ± 0., N=2

Fig. 7. YIELD OF SURIMI (80% WATER)

ATLANTIC COD



□ LAB SCALE (fillet)
AVERAGE = 43.7 ± 2.1, N=10

▲ LAB SCALE (frame)
AVERAGE = 5.1 ± 1.8, N=3

◆ PILOT SCALE (fillet)
AVERAGE = 23.3 ± 4.1; N=12

▼ PILOT SCALE (split cod)
AVERAGE = 39.0 ± 5.2, N=2

Fig. 8. MOISTURE CONTENT OF SURIMI

ATLANTIC COD

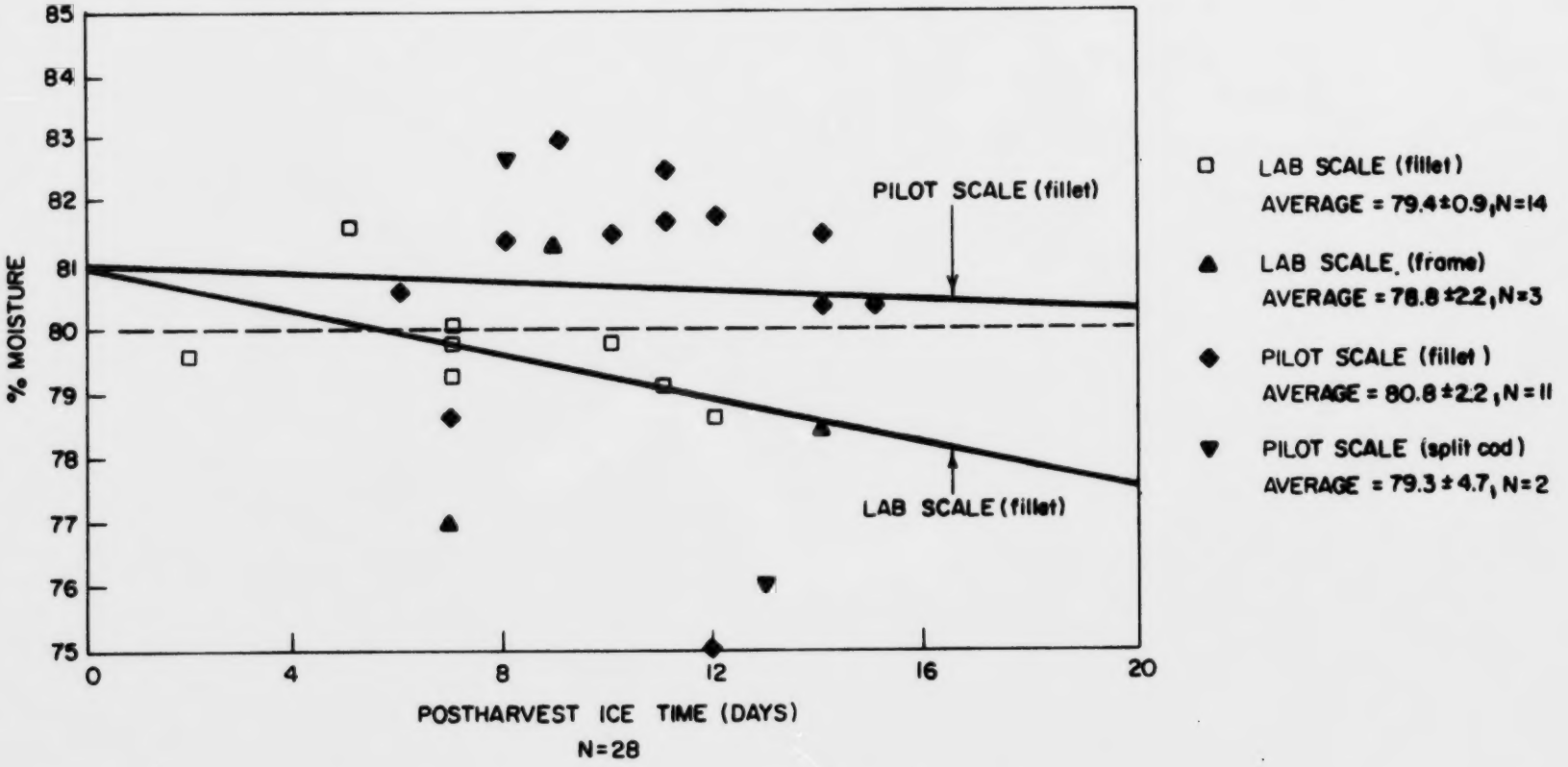
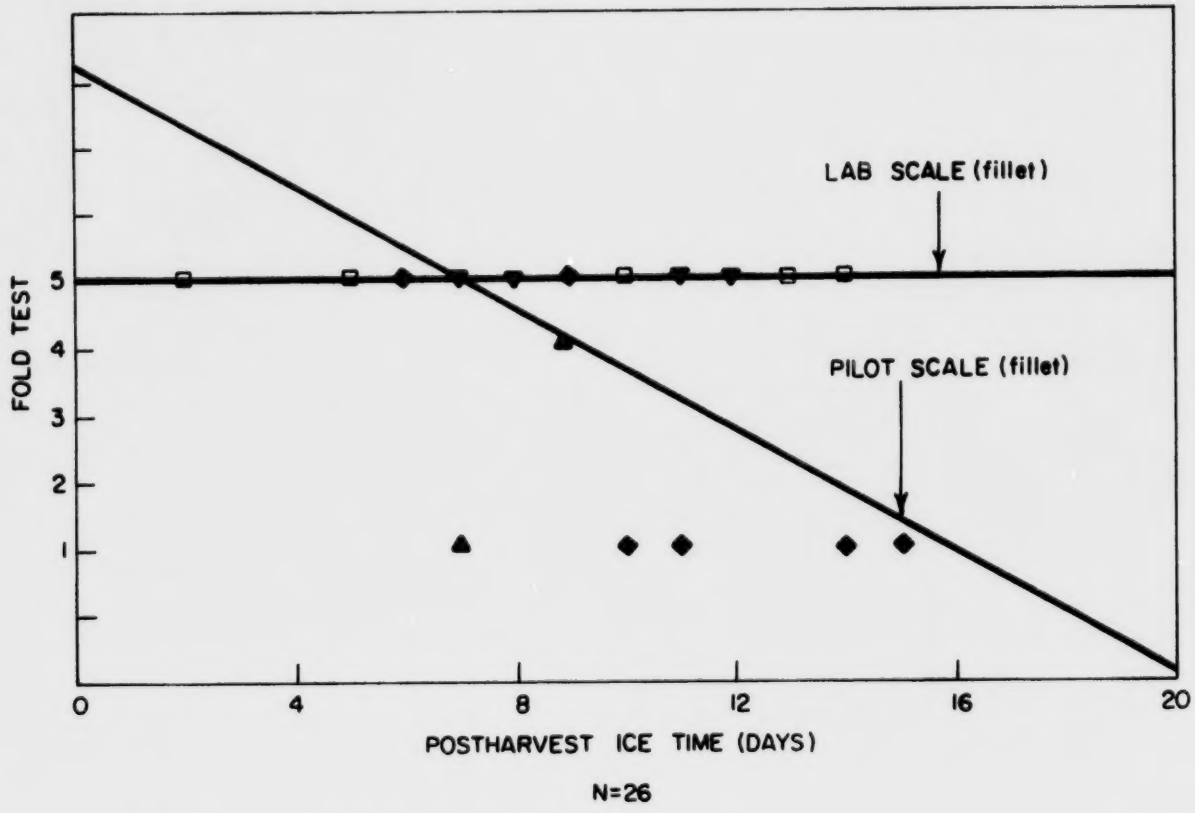


Fig. 9. FOLD TEST OF COOKED (90°C) SURIMI

ATLANTIC COD



□ LAB SCALE (fillet)
AVERAGE = 5 ± 0, N = 9

▲ LAB SCALE (frame)
AVERAGE = 2 ± 2, N = 3

◆ PILOT SCALE (fillet)
AVERAGE = 3 ± 2, N = 12

▼ PILOT SCALE (split cod)
AVERAGE = 5 ± 0, N = 2

Fig. 10. GEL STRENGTH OF COOKED (90°C) SURIMI

TORSIONAL FAILURE

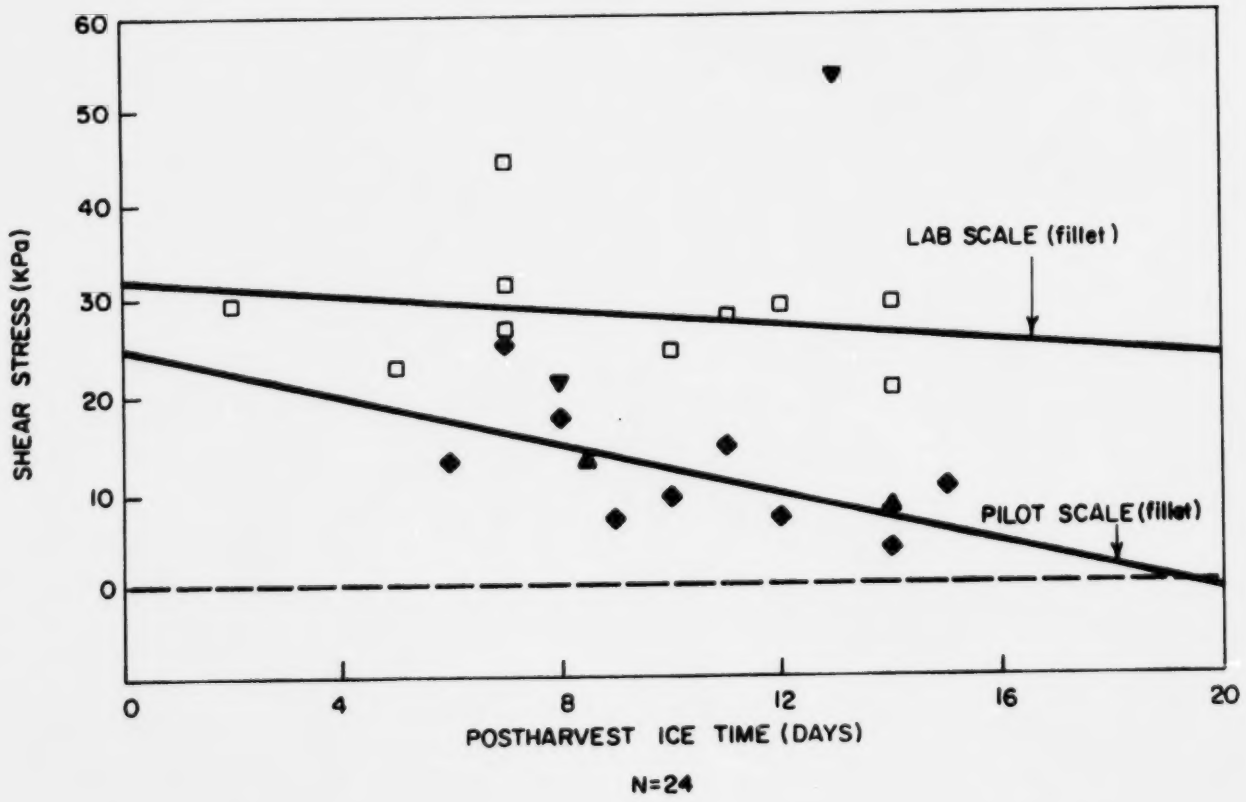
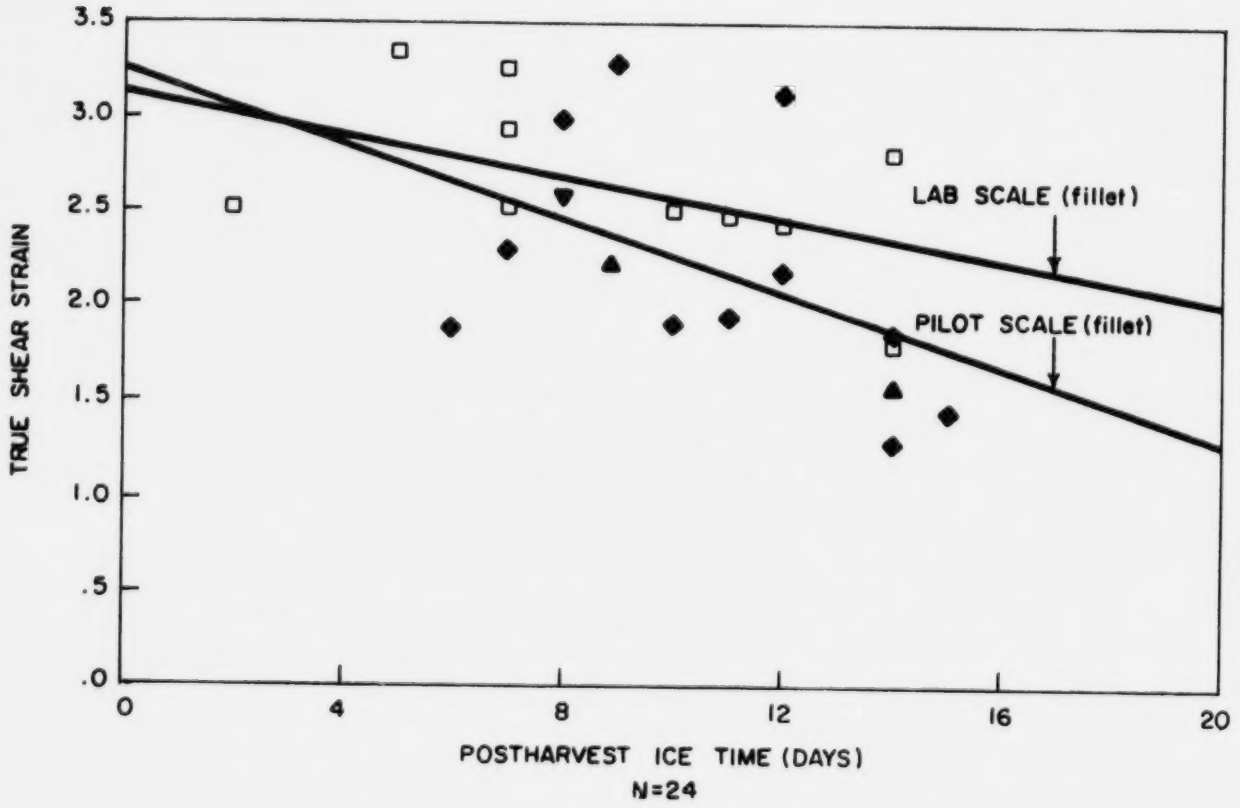


Fig. 11. GEL DUCTILITY OF COOKING (90°C) SURIMI

TORSIONAL FAILURE



□ LAB SCALE (fillet)
AVERAGE = 2.65±0.45, N= 10

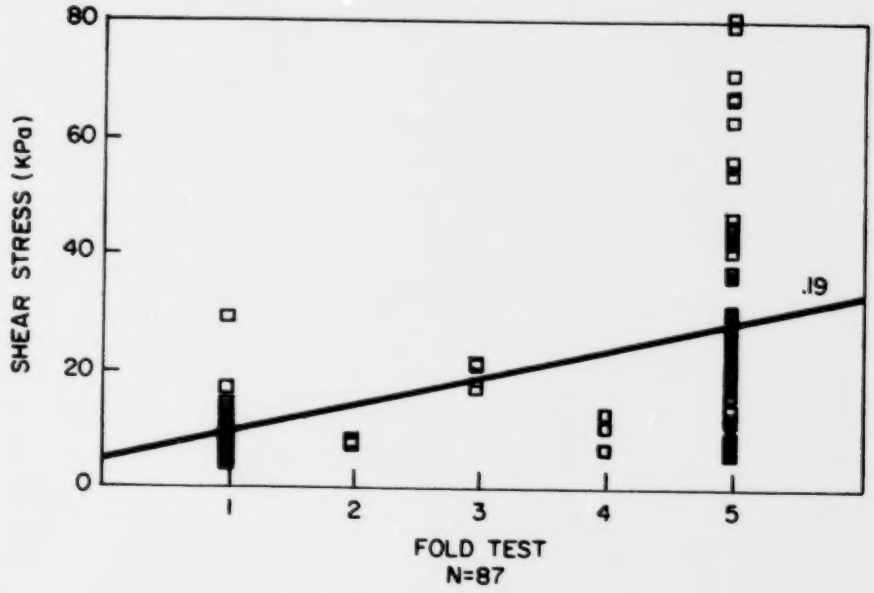
▲ LAB SCALE (frame)
AVERAGE = 1.88±0.45, N= 2

◆ PILOT SCALE (fillet)
AVERAGE = 2.21±0.73; N= 10

▼ PILOT SCALE (split cod)
AVERAGE = 2.48±0.13, N= 2

Fig. 12. TORSION FAILURE vs FOLD TEST

GEL STRENGTH



GEL DUCTILITY

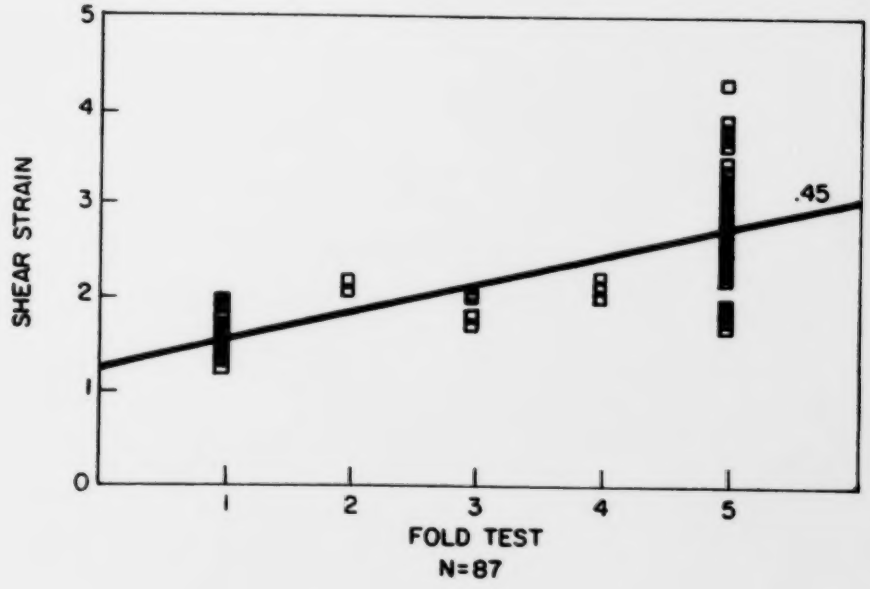
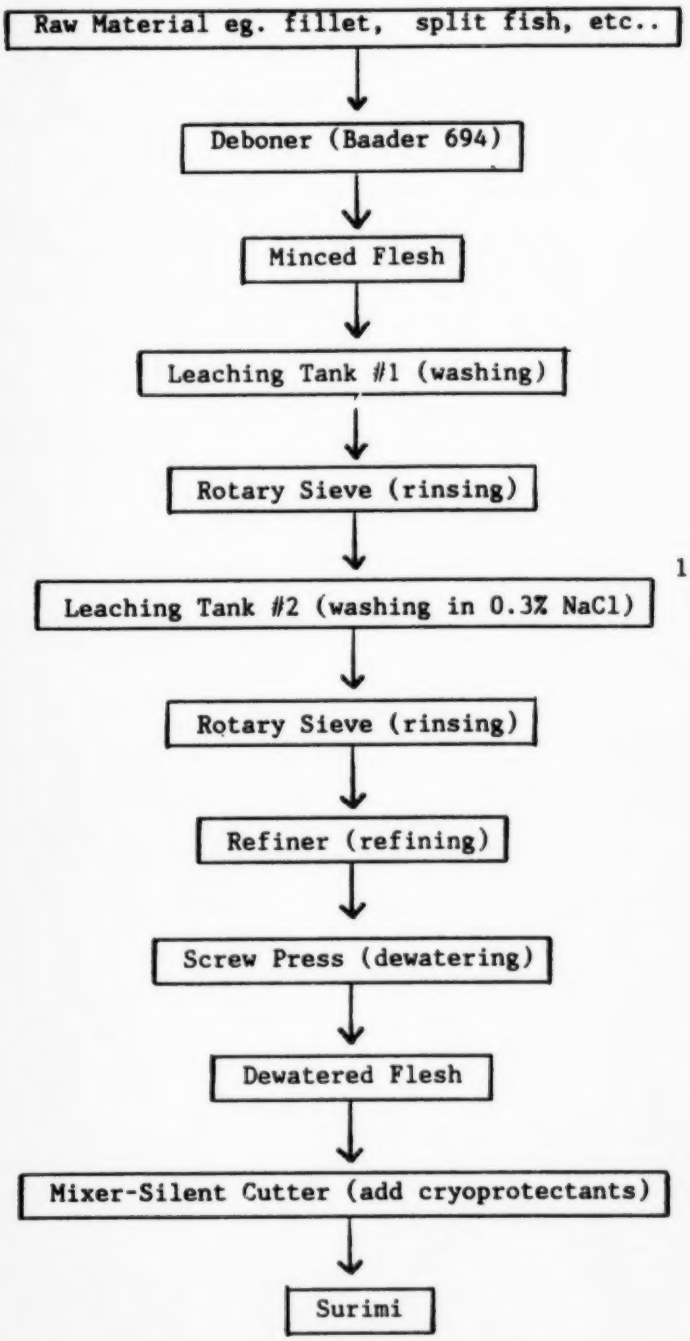


Figure 13 - A Flow Chart of the Surimi Production Process Using the Bibun Pilot Line



[1] In this study 0.14% NaCl was used on all surimi produced from cod fillets. 0.3% NaCl was used during all other studies (cod frames, split cod, haddock, flounder and redfish).

Appendix A. Summary of Test Results of Lab Scale Surimi Produced from Cod Fillets.

Sample	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain		
				Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C
2 day old cod	Dec.16/85	79.5	7.09	55.0	77.5	74.6	77.5	5	5	5	7	44.2	28.3	30.1	29.2	3.01	2.52	2.50
5 day old cod	Jan.22/86	81.5	7.09	53.1	77.9	78.6	78.1	5	5	5	8	43.1	22.9	11.8	22.7	3.10	3.47	3.34
7 day old cod	Jan.14/86	79.7	7.12	59.9	76.4	77.3	78.3	5	3	-	6	47.6	25.5	20.9	31.1	2.15	2.04	2.52
7 day old cod	Jan.14/86	80.0	7.03	61.3	80.4	79.2	80.2	5	5	5	7	46.9	40.4	43.0	44.2	3.25	3.81	3.24
7 day old cod	Jan.24/86	79.2	7.06	54.1	78.6	77.4	78.9	5	5	5	8	41.4	23.9	25.5	26.5	2.94	3.04	2.93
10 day old cod	Jan.27/86	79.7	7.22	54.0	78.5	75.8	77.3	3	5	5	7	43.2	16.8	22.8	24.2	2.03	2.63	2.48
11 day old cod	Jan.28/86	79.1	7.17	55.1	78.1	72.2	76.2	5	5	5	9	42.2	29.5	26.6	27.8	2.29	2.39	2.45
12 day old cod	Jan.29/86	78.6	7.42	54.6	77.2	74.2	77.5	5	5	5	8	41.4	27.2	28.8	29.0	2.31	2.40	2.41
14 day old cod	Jan.21/86	78.4	6.86	54.9	75.8	75.4	74.5	3	3	5	5	43.3	21.4	17.9	20.3	1.70	1.80	1.79
14 day old cod	Jan.21/86	78.4	7.07	61.0	77.3	76.2	78.0	5	5	5	5	43.3	30.3	22.0	29.0	2.74	3.01	2.80

Appendix B. Summary of Test Results of Lab Scale Surimi Produced from Cod Frames.

Sample	Process Date	Moisture Content	pH	Colour ("L") Value				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain		
				Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C
7 day old cod	Jan.14/86	76.9	7.2	48.4	63.1	63.5	68.3	1	1	1	2	6.9	-	-	-	-	-	-
9 day old cod	Jan.30/86	81.2	7.2	44.8	69.9	69.7	69.7	4	2	4	3	4.8	10.2	7.7	12.7	2.13	2.05	2.20
14 day old cod	Jan.21/86	78.4	7.1	-	-	65.7	69.5	-	1	1	4	3.8	18.4	13.1	7.8	1.50	1.66	1.56

Appendix C. Summary of Test Results of Pilot Scale Surimi Produced from "Split" Cod and Cod Frames.

Sample	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain		
				Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C
Split Cod, Age ?	Feb.12/86	75.6	7.1	51.9	76.6	73.2	73.3	5	5	5	9	35.3	50.0	51.3	56.2	2.37	2.24	2.58
Split Cod, 8 day old	Mar.14/86	82.6	7.2	32.7	75.6	76.7	73.1	5	1	5	8	33.8	21.7	8.1	21.4	2.53	1.39	2.57
Split Cod, 13 day old	Feb.20/86	76.0	7.0	49.1	68.9	72.8	72.9	5	5	5	8	44.1	45.6	41.8	53.2	2.29	2.44	2.38
Cod Frame, 10 day old	Feb. 8/86	73.9	7.1	48.8	72.2	71.4	71.3	5	5	5	9	-	44.5	43.1	79.8	2.73	2.74	3.26

Appendix C - Continued.

Sample	Process Date	Deformation (cm)	40°C Energy (Joules)	40°C Work (Joules)	Deformation (cm)	60°C Energy (Joules)	60°C Work (Joules)	Deformation (cm)	90°C Energy (Joules)	90°C Work (Joules)	40°C Newtons/gms Hardness 1st Compression	40°C Newtons/gms Hardness 2nd Compression	60°C Newtons/gms Hardness 1st Compression	60°C Newtons/gms Hardness 2nd Compression	90°C Newtons/gms Hardness 1st Compression	90°C Newtons/gms Hardness 2nd Compression
Split Cod, Age	Feb.12/86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Split Cod, 8 day old	Mar.14/86	.98	.020	.010	.92	.016	.008	.77	.010	.055	.63	.56	.63	.56	.52	.46
Split Cod, 13 day old	Feb.20/86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cod Frame, 10 day old	Feb. 8/86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix D. Summary of Test Results of Pilot Scale Surimi Produced from Cod Fillets.

Sample	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain		
				Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C
Cod, 6 day old	Mar.12/86	80.5	7.3	55.4	78.5	80.1	81.3	5	5	5	9	28.92	17.4	11.1	13.0	2.16	1.92	1.87
Cod, 7 day old	Mar.13/86	78.6	7.2	-	-	-	-	5	5	5	9	28.2	37.0	28.5	25.2	2.85	2.50	2.28
Cod, 8 day old	Feb.25/86	81.3	7.3	51.8	80.2	80.1	80.3	5	5	5	9	23.9	22.2	19.2	17.6	3.80	2.69	2.98
Cod, 9 day old	Feb.26/86	82.9	7.3	55.5	81.3	80.0	78.6	5	5	5	9	22.4	11.0	6.3	7.1	3.73	4.26	3.27
Cod, 10 day old	Feb.27/86	81.4	7.3	52.9	78.9	76.7	79.7	2	4	1	10	26.4	7.4	6.2	9.1	2.17	1.99	1.89
Cod, 11 day old	Feb.28/86	85.9	7.9	53.0	79.0	79.4	79.4	1	1	1	9	10.9	-	-	-	-	-	-
Cod, 11 day old	Mar. 7/86	81.6	7.6	48.8	77.6	76.4	77.5	1	1	1	9	13.2	-	5.5	14.5	-	1.51	1.93
Cod, 11 day old	Mar.19/86	82.4	7.7	57.6	82.1	81.1	80.5	5	5	5	9	23.6	5.3	6.2	6.8	1.80	2.15	2.17
Cod, 12 day old	Feb.19/86	74.8	7.0	53.0	74.6	74.3	76.0	5	5	5	9	27.4	66.7	70.3	79.3	2.59	3.26	3.11
Cod, 12 day old	Mar.20/86	81.7	7.3	-	-	-	-	5	5	5	9	27.7	7.3	8.1	8.1	1.68	1.76	1.84
Cod, 14 day old	Mar. 3/86	80.3	7.8	55.9	78.3	77.6	77.4	1	1	1	9	24.9	4.4	3.5	3.5	1.19	1.28	1.28
Cod, 14 day old	Mar.10/86	81.4	7.6	-	-	-	-	1	1	1	9	21.0	12.0	8.3	10.2	1.63	1.44	1.45
Cod, 15 day old	Mar. 4/86	80.3	7.2	54.2	78.1	77.0	72.1	1	1	1	9	23.1	-	-	-	-	-	-
*Trap Cod 1 day old	Aug./85	76.1	6.3	58.6	76.0	74.6	74.8	4	1	1	7	-	22.8	9.2	18.9	1.89	1.38	1.72

*A surimi sample produced commercially from Trap Cod in the plant at Terra Nova Fisheries, Clarenville, Nfld.

Appendix D - Continued.

Sample	Process Date	40°C			60°C			90°C			40°C		60°C		90°C	
		Deformation (cm)	Energy (Joules)	Work (Joules)	Deformation (cm)	Energy (Joules)	Work (Joules)	Deformation (cm)	Energy (Joules)	Work (Joules)	Newtons /gms Hardness 1st Compression	Newtons /gms Hardness 2nd Compression	Newtons /gms Hardness 1st. Compression	Newtons /gms Hardness 2nd. Compression	Newtons /gms Hardness 1st. Compression	Newtons /gms Hardness 2nd. Compression
Cod, 6 day old	Mar.12/86	.96	.014	.007	.92	.009	.004	.97	.018	.006	2.06	1.86	2.20	1.93	1.92	1.68
Cod, 7 day old	Mar.13/86	.98	.020	.010	.92	.016	.008	.93	.016	.008	2.10	1.83	1.83	1.48	2.12	1.80
Cod, 8 day old	Feb.25/86	1.38	.021	.011	1.33	.017	.008	1.33	.011	.006	-	-	-	-	-	-
Cod, 9 day old	Feb.26/86	1.13	.006	.003	1.27	.006	.003	1.29	.008	.004	-	-	-	-	-	-
Cod, 10 day old	Feb.27/86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cod, 11 day old	Feb.28/86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cod, 11 day old	Mar. 7/86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cod, 11 day old	Mar.19/86	.88	.005	.003	.94	.005	.003	.81	.004	.002	.98	.86	1.07	.92	.87	.79
Cod, 12 day old	Feb.19/86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cod, 12 day old	Mar.20/86	.79	.008	.004	.81	.007	.003	.99	.009	.005	.98	1.07	.87	.86	.92	.77
Cod, 14 day old	Mar. 3/86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cod, 14 day old	Mar.10/86	.68	.004	.002	.56	.002	.001	.60	.003	.001	.22	.20	.19	.18	.19	.18
Cod, 15 day old	Mar. 4/86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
*Trap Cod 1 day old	Aug./85	.62	.012	.006	.61	.008	.004	.66	.016	.008	4.67	4.19	3.50	2.90	3.95	3.58

*A surimi sample produced commercially from Trap Cod, in the plant at Terra Nova Fisheries, Clarenville, Nfld.

Appendix E. Summary of Test Results of Pilot Scale Surimi Produced From Redfish, Flounder and Haddock.

Sample	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain		
				Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C
Redfish, Split 5 days old	Feb. 6/86	80.0	7.4	60.2	78.6	77.5	75.5	5	5	5	8	-	22.6	35.8	27.2	2.74	3.75	2.91
Redfish, Fillet 7 days old	Feb.10/86	80.4	7.5	56.5	81.2	80.5	80.8	5	5	5	9	-	16.1	16.1	18.1	2.71	2.71	3.91
Flounder Frame 11 days old	Feb.13/86	77.1	7.5	63.6	73.2	71.8	70.0	1	1	1	9	10.0	-	-	-	-	-	-
Flounder Frame 12 days old	Feb.14/86	77.1	7.5	63.6	73.2	71.8	70.0	1	1	1	9	12.0	17.0	12.8	29.4	1.92	1.45	1.81
Haddock Fillet 7 days old	Feb.17/86	76.1	7.1	50.2	76.0	75.4	76.3	5	5	5	9	*52.7	62.5	55.8	66.0	3.63	3.79	3.89

N.B. Haddock surimi yield was expressed as a percentage of skinless fillets and the flounder surimi yields have been expressed as a percentage of dressed weight.

PART

2

A STUDY OF THE USE OF COD, COD BY-PRODUCTS AND CRUSTACEAN BY-PRODUCTS FOR SURIMI AND SURIMI-BASED PRODUCTS: PART II - PHYSIOLOGY STUDIES

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ABSTRACT

Haard, N. October 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part II - Physiology Studies. Can. Ind. Rep. Fish. Aquat. Sci. 177: viii + 34 p.

High grade surimi can be produced from bled cod held on ice for up to 7 days and bled winter cod iced for 12 days. Better quality surimi can be made from cod fillet held at 0 ± 0.2°C than from cod held at -3 ± 1°C. Bled summer cod retains its quality for surimi production 50% longer than unbled cod. The apparent viscosity of a simple actomyosin extract from muscle is a sensitive indicator of kamaboko making potential of cod surimi. At this time Ca^{+2} ATPase does not appear to be a reliable indicator of gel strength potential. Proteolytic hydrolysis does not appear to play a significant direct role in the loss of gel strength potential. However, it may play an indirect role in the loss of gel strength potential. However, it may play an indirect role in the loss of actomyosin viscosity, which is associated with loss in gel strength potential.

RÉSUMÉ

Haard, N. October 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part II - Physiology Studies. Can. Ind. Rep. Fish. Aquat. Sci. 177: viii + 34 p.

On peut obtenir du surimi de qualité supérieure à partir de morue saignée gardée en glace jusqu'à sept jours et de morue d'hiver saignée gardée en glace pendant 12 jours. Des filets de morue gardée à 0 x 0,2°C fournissent une meilleure qualité de surimi que la morue gardée à -3 + 1°C. La morue d'été saignée conserve sa qualité pour la production de surimi 50% plus longtemps que la morue non-saignée. La viscosité apparente d'un extrait simple d'actomyosine musculaire est un indicateur sensible du potentiel de production de kamaboko à partir de surimi de morue. Actuellement, la Ca^{+2}ATPase ne semble pas être un indicateur fiable du potentiel de résistance du gel. L'hydrolyse protéolytique ne semble pas jouer un rôle direct important dans la perte de potentiel de résistance du gel mais elle peut toutefois y contribuer indirectement. De plus, cette hydrolyse peut être impliquée indirectement dans la réduction de la viscosité de l'actomyosine qui découle de la perte de potentiel de la résistance du gel.

PREFACE

A contract was awarded to a research team from the Newfoundland and Labrador Institute of Fisheries and Marine Technology (The Marine Institute) and Memorial University to study the potential of selected Canadian Atlantic fish species and shellfish processing wastes to produce surimi and shellfish flavours. Research to develop methodology for rapidly determining the potential of raw materials to produce surimi was initiated, objective laboratory techniques for evaluating the quality of surimi were established, a pilot line for producing surimi was installed, surimi was produced from cod and other groundfish. Some biochemical indices of cod were analysed under various conditions of storage and methods were established which may assist as predictors of surimi potential from cod and possibly other species. Crab process wastes and scallop process wastes were analysed for their contents of flavour-active components. Methods of concentrating flavours were identified.

Three separate publications from this contract were issued. Correct citation for these are:

Chandra, C.V. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part 1 - Raw Material Assessment.

Haard, N. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part 11 - Physiology Studies.

Haard, N. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part 11 - Physiology Studies.

Voigt, M.N. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part 111 - Shellfish Flavour Extraction Studies.

The opinions and interpretations expressed in the report are those of the author, and do not necessarily reflect those of the Department of Fisheries and Oceans.

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INTRODUCTION

The myosin molecule comprises about 40% of the total protein in fillets from Atlantic cod (Gadus morhua). Myosin and associated contractile proteins are concentrated during the manufacture of surimi such that more than 60% of the protein in surimi is myosin. The gel-forming property of surimi is directly related to its content of native myosin. The mechanism by which myosin and related proteins form a gel as a consequence of heat treatment is not fully understood at this time.

Myosin is a large rod shaped molecule having a molecular weight of approximately 500,000 daltons. It contains two identical heavy chains which are wound around each other to form a lollypop shaped structure. Associated with the globular head of myosin are additional proteins called light chains. There are two classes of light chain, one of which is called "alkali light chain" and is essential for myosin ATPase (Adenosine Triphosphatase) activity. The globular head of myosin is responsible for the ATPase activity of the molecule and its ability to interact with actin.

Actin is the second most abundant muscle protein. It comprises 15-30% of surimi protein and probably exists in muscle as fibrous actin (F-actin). The latter is made up of monomeric units of globular actin (G-actin) which has a molecular weight of about 40,000 daltons.

When purified actin and myosin are mixed in vitro a complex called actomyosin is formed. The protein interactions that occur during the onset of rigor appear to involve a similar interaction of actin and myosin. The consequence of actin and myosin interactions, e.g. during rigor, on the

functional characteristics of surimi is not fully understood at this time. For meat products, the protein interactions that occur during rigor hinders the ability of salt to improve the water binding and swelling of meat paste. It is likely that a similar type of combination between actin and myosin molecules occurs in surimi and therein has importance to its functional properties. Overnight extraction of muscle of surimi with a buffer of ionic strength about 0.6 yields a crude actomyosin solution, sometimes called "myosin B". Actomyosin has a high viscosity and like myosin has ATPase activity. The high viscosity of actomyosin appears to be the result of its long rod like structure.

Myosin appears to be the most important component of muscle tissue or surimi with respect to gel-forming ability. Actin assists in this process by forming F-actomyosin which in turn interacts with myosin. The head portion of myosin undergoes irreversible aggregation (involving disulfide interaction) during heating of meat paste and this appears to contribute to formation of the three dimensional network of the gel. The elongated tail portion of the myosin molecule undergoes a partial unravelling during heating of meat paste and this also contributes to the formation of a three dimensional network. Hence, gel formation occurs when myosin is denatured under strictly controlled conditions. However, denaturation of myosin prior to heating under strictly controlled conditions can result in a loss of gel-forming ability.

Fish myofibrillar protein, notably myosin, is much more sensitive to denaturation than that from land animals. The mechanism by which fish proteins denature is not completely understood. However, it involves

aggregation of myosin and/or actomyosin initially by non-covalent bonds (weak ionic interactions between protein molecules themselves or hydrophobic interactions with the aid of free fatty acids formed as a result of lipid hydrolysis) and in some systems secondarily by covalent crosslinks (brought about by disulfide linkages and aldehydes formed by lipid oxidation or trimethylamine oxide catabolism). Water washing minced fish muscle and addition of cryoprotectants to the washed product serves to markedly improve the stability of myofibrillar proteins during frozen storage.

Proteolytic enzymes which hydrolyze myosin or associated myofibrillar proteins may also decrease the gel-forming ability of fish paste. Proteolytic enzymes may decrease the gel-forming ability of fish proteins during postmortem storage of muscle prior to the manufacture of surimi or may act during the time the fish paste is heated to form a gel. An example of proteolytic action during postmortem storage is the rapid loss in gel strength of parasitized Peruvian hake muscle due to proteases associated with protozoan infection. Protein hydrolysis during the heating of fish paste is exemplified by alkaline proteases in croaker (Lin, T.S. and T.C. Lanier. 1980) which appear to hydrolyze proteins during intermediate temperatures (e.g. 60°C) of heating during gel-formation.

The key mechanistic factor(s) which causes the loss in ability of myosin from cod and other raw materials in Newfoundland to form a three dimensional network or gel during heating is not known at this time. For

several reasons, understanding these factors is necessary for the prudent development of a surimi industry. One reason is that understanding these factors may provide insight into the best choice of raw material for use in surimi manufacture. Intraspecific factors, such as water temperature, migratory history, spawning, year-class, feeding history, etc. as well as harvest and postharvest catching and handling methods are probably as important as or more important than species differences with respect to suitability of the raw material. A second reason is that such knowledge will provide a scientific rather than an empirical basis for trouble shooting unexpected problems which will arise in the industry from time to time. For example, knowing that the thermal instability of myosin from aged fish is lower than that of myosin from very fresh fish indicates that the surimi processor must exercise more stringent temperature control over the process when the raw material is not fresh. A third reason is that such knowledge can form the basis of a method to judge or grade raw material intended for use in surimi manufacture. Grading systems currently employed in the fish processing industry are not well suited for the surimi industry because they are more or less intended to assess the progress of bacterial spoilage. This type of grading system may bear little relation to the suitability of the raw material for surimi manufacture.

MATERIALS AND METHODS

1. BIOLOGICAL MATERIAL -

Atlantic cod (Gadus morhua) purchased from local fishermen were used for preliminary studies. The majority of studies were conducted with fish harvested during the trap season and maintained in a 181,840 litre (40,000

gallon aquarium at Marine Science Research Laboratory Memorial University. Fish were normally approximately 55cm in length.

2. HANDLING -

Specimens were removed from the holding tank, stunned with a blow to the head, and bled by cutting the jugular and submerging in sea water for approximately 5 minutes. In certain studies, fish were not bled after stunning. All fish were immediately packed in ice and after approximately 2 hours were filleted. Fillets were vacuum packed and stored at 0 ± 0.2°C or in some studies at -3 ± 1°C for up to 21 days.

3. LABORATORY SURIMI -

Surimi was prepared by hand mincing a 1 kg fillet; washing the mince with 8 L tap water (approximately 8°C) for 5 minutes; decanting the slurry through a China cap strainer (1mm bores), repeating the water wash three additional times; washing the mince with 8 L 0.14% NaCl (4°C), and dewatering the washed mince in a muslin bag with a Carver press at 69,000 KPA, (10,000 psi) for 5 minutes.

4. KAMABOKO -

Kamaboko was prepared by blending 4% sucrose, 4% sorbitol, 0.3% sodium tripolyphosphate with the dewatered mince. To this was added 3% NaCl with chopping and blending to form a paste. The resulting dough was steamed with a Rival automatic steamer using 250 ml water.

A fold test to measure elasticity was performed on samples of the Kamaboko 18 hours after cooking. "AA" indicates no cracks or breaks when 5 x 35 mm discs are folded in quarters.

5. ACTOMYOSIN -

Actomyosin was prepared from fillets or from surimi by the following procedure at 0-2°C. Raw material (10g) was suspended in 30 ml 0.05 N imidazole - HCl, pH 7.0, centrifuged at 15,00 x g for 20 minutes and the supernatant discarded. This step was repeated twice more. The residue was suspended in 60 ml .05N imidazole - HCl containing 0.6N KCl and stirred for 18 hours at 4°C. the actomyosin was recovered as a supernatant after centrifugation at 15,000 x g for 20 minutes. This type of actomyosin preparation is sometimes called "Myosin B" by other workers.

6. APPARENT VISCOSITY -

Actomyosin was adjusted to 2.5 mg/ml with KCL buffer and held at 5°C for 30 minutes. Samples (1.8 ml) were centrifuged at 12,000 rpm at 4°C and the viscosity of the supernatant was determined at 5°C with a Wells - Brookfield microviscometer model LVT at a spindle speed of 6 rpm. For certain studies the samples were preincubated at temperatures higher than 5°C in order to determine thermal stability of actomyosin.

7. ATPASE -

The protein adjusted actomyosin (2.5 mg/ml) was dialyzed against 0.6N KCl, 4°C to remove buffer. A 1 ml aliquot as assayed in 9.6 ml of either activating or relaxing reaction mixtures. Activating reaction mixture contained 0.05N KCl, 4 mM $MgCl_2$, and 0.25 M $CaCl_2$, pH 7.4. Relaxing reaction mixture contained 0.05N KCl, 4 mM $MgCl_2$, and 1 mM EGTA, pH 7.4 The reaction was started by adding 0.4 ml 100 mMATP - $MgCl_2$. The raction mixture was titrated with 0.01 N KOH to maintain the pH at 7.4 using a Metrohm Herisau Dosimat and Impulsomat at 5°C. From the KOH titer, the equivalents of protons formed from ATP (Adenosine Triphosphate) hydrolysis were calculated. The same procedure was used to measure muscle ATPase, where approximately 0.2 g muscle replaced the actomyosin solution.

Samples of muscle (1 g), free of mycommata connective tissue, were mixed with 9 ml sodium dodecylsulfate, polyacrylamide gel electrophoresis (SDS-PAGE) sample buffer, boiled for 15 minutes and homogenized to extract protein. The protein was separated from insoluble matter by centrifugation of the mixture at 5,000 x g for 15 minutes. Electrophoresis was performed on Laemmli slab gel samples (18 x 20 cm) for 6 hours at 35 ma per plate using a BioRad Protean II unit and manufacturers instructions.

RESULTS

Influence of storage temperature on actomyosin denaturation - A faster rate of actomyosin denaturation occurred during storage of cod fillets at -3 ± 1.0°C than during storage at 0 ± 0.2°C (Figure 1, commercial fish; Figure 2, tank fish). Surimi prepared from fish held on ice for several days had lower gel strength than that from fish which was freshly harvested. Measurement of the apparent viscosity of actomyosin from surimi indicated the actomyosin fraction from surimi with low gel strength was denatured (see below). These results differ from those of a previous study which showed that a lower rate of actomyosin denaturation occurred during storage of cod muscle at -3 ± 0.1°C compared to 0 ± 0.2°C (Simpson and Haard 1986). Hence it appears that the benefit of partial freezing, with respect to minimizing protein denaturation, is dependent on ability to stringently control the temperature of the storage environment, e.g. ±0.1°C. Due to the high cost of currently available freezers which can meet this rigorous temperature control, the use of partial freezing to extend the useful storage life of cod for surimi manufacture would not appear to be practical.

Influence of sea water temperature and season of catch on actomyosin denaturation during storage on ice - A faster rate of actomyosin denaturation occurred during ice storage of fish harvested in July than in fish harvested in February. When fish which were harvested in July were held live in an aquarium at 0°C for 3 - 4 weeks prior to sacrifice, the rate of post-mortem actomyosin denaturation was slower and like that of fish harvested in February (Figure 3A). For bled cod harvested from a tank in July - August and held on ice for more than 5 - 7 days the resulting surimi did not exhibit an "AA" fold test; whereas a high surimi gel strength was obtained with cod harvested from tanks at ambient sea water temperature in February and held on ice for as long as 12 days (Figure 4A). These results indicate that cod harvested from grounds which have a low water temperature have a longer acceptable ice time for use in surimi than cod harvested from fishing areas which have a higher water temperature. Cold acclimated cod also appear to have a higher concentration of extractable actomyosin prior to post-mortem storage (Table 1) and would therefore be expected to yield more surimi per mass of mince or fillet.

Influence of bleeding cod at harvest time on actomyosin denaturation during ice storage - A slower rate of actomyosin denaturation occurred during storage of cod fillet (fish harvested in July - August) on ice when they were bled at the time of sacrifice (Figure 5). Again, slower rate of actomyosin denaturation was associated with a slower rate of loss of surimi gel strength. Similar results were also obtained with fish harvested from tanks held at ambient sea water temperature in February (Figure 4B). Graduate student (PHD., Memorial University of Newfoundland) Mike Hawco has

shown that in vitro mixing of cod fish blood with extracted cod fish actomyosin results in rapid denaturation of the actomyosin solution (M. Hawco PERS. COMM). Therefore it appears that blood may act to directly accelerate protein denaturation in post-mortem cod. The results indicate that the useful ice storage life of cod used for surimi manufacture may be extended by as much as 50 to 100 per cent by bleeding fish at harvest. Additional work is needed to verify these results with fish harvested and bled by fishermen and processed with the pilot surimi line at Newfoundland and Labrador Institute of Fisheries and marine Technology.

Molecular basis of actomyosin denaturation during ice storage of post-mortem cod - Extractability of actomyosin from cod muscle decreased gradually as a function of ice time. This appears to be associated with non-covalent aggregation of the actomyosin since the protein which becomes insoluble in buffered salt solution is readily solubilized in solvent containing detergent and is apparently not different from native cod actomyosin. A more sensitive indication of actomyosin denaturation than loss of salt extractable protein is the apparent viscosity of the extractable actomyosin. Extractable actomyosin was prepared from either stored cod fillet or its surimi product. Loss in surimi gel strength was highly correlated with a decline in the apparent viscosity of extractable actomyosin (Figures 6 - 8). Actomyosin viscosity appears to be a much more sensitive indicator of post-mortem denaturation of actomyosin than is the fold test.

The molecular size of cod myosin appears to increase slightly during storage of fish on ice as evidenced by the broader, somewhat faster moving band representing cod myosin (Figures 9 and 10). This may indicate limited proteolytic hydrolysis of myosin occurs during ice storage. The average molecular size of myosin decreased from approximately 185,000 daltons to approximately 165,000 daltons during 11 days storage. The second major protein in cod surimi, actin, does not appear to change during ice storage. Other changes in muscle protein were noted (see bands 1, 2 and 3, Figures 9 and 10). A 68,000 dalton protein (band #1) and a 35,000 dalton protein (band #3) gradually disappeared during 11 days storage on ice. A 37,000 dalton protein (band #2) gradually increased during this same storage time. This experiment indicates that the decline in actomyosin viscosity is not directly caused by the gross hydrolysis of myosin or by the formation of myosin or actomyosin aggregates stabilized by covalent cross linkages. It is possible that the relatively minor hydrolysis of proteins may be directly related to the denaturation of myosin in muscle. Denaturation, (unfolding or aggregation), would not be detected by gel electrophoresis of muscle proteins because the detergents employed denature the protein. However, sedimentation velocity of denatured actomyosin (low viscosity) showed that the apparent molecular size of denatured actomyosin is greater than that of native actomyosin. From these experiments we can conclude that the decline in viscosity and gel-forming ability of cod actomyosin, that occurs during storage of the fish on ice, is directly related to denaturation - aggregation phenomena which involve non-covalent interactions. In other words, the loss in actomyosin viscosity does not

appear to involve covalent cross linkage (e.g. from formation of formaldehyde from trimethylamine oxidate reduction) nor does it appear to be the direct result of protein hydrolysis leading to a large change in the molecular size of heavy chain myosin.

Relationship between ATPase activity and actomyosin denaturation during storage of cod in ice - Skeletal muscle contains a myriad of different enzymes which catalyze hydrolysis of adenosine triphosphate (ATP). Muscle ATPase activity includes enzymes involved with the transport of ions and other solute molecules across cell membranes, notably those of the sarcoplasmic reticulum and mitochondrion which function in the transport of calcium ions. Pure myosin is also an ATPase and its activity requires Ca^{+2} and is inhibited by Mg^{+2}. The myosin of actomyosin also has ATPase activity, however its activity is normally stimulated by Mg^{+2}. Protein denaturation is normally accompanied by loss in biochemical function, i.e. loss of enzyme activity. Previous studies in Japan have shown that myosin or actomyosin ATPase activity of Alaska pollack or Peruvian hake appears to be a useful indicator of the gel-forming ability of surimi. We have studied the activity of various ATPase fractions isolated from cod muscle as a function of ice storage time to get insight into whether or not the ATPase activity of intact muscle could be used as a means of evaluating the extent of actomyosin denaturation. Our main objectives were to develop a kinetic method to measure ATPase activity of intact muscle tissue and to determine whether muscle ATPase activity is an indicator of actomyosin denaturation.

A pH stat method was found to be a simple kinetic method for measuring ATPase activity of intact cod muscle. The reaction of the hydrolysis of ATP is as follows:

$$ATP + H_2O \text{ ---- } ADP + Pi + H^+$$

ADP = ADENOSINE DIPHOSPHATE

Pi = INORGANIC PHOSPHATE

The principle of this assay system is that the formation of protons during ATP hydrolysis can be measured from the equivalents of base required to maintain the pH. An advantage of this method over other end point methods, i.e. which measure Pi formed, is that the reaction can be monitored directly and continuously and is therefore amenable to analysis of ATPase by tissue surface sensor techniques. A limitation of this method is the marked decrease in sensitivity below pH 7 because of the buffering capacity of proteins in this pH range.

Myosin was purified from prerigor cod muscle by a modification of Connell's method. The Ca^{+2} activated ATPase activity of the purified myosin decreased by about 90% over 18 days storage at 4°C (Figure 11). The Mg^{+2} activated activity of this enzyme was approximately 0.25 that of the Ca^{+2} activated activity and decreased at a slower rate during storage.

Sarcoplasmic ATPase, soluble in low ionic strength buffer, was isolated from cod which had been glycerinated prior to analysis. The major component of sarcoplasmic ATPase is probably from the sarcoplasmic reticulum. Sarcoplasmic ATPase activity from cod held on ice increased

approximately five fold during the first week of storage and thereafter decreased (Figure 12). The Ca^{+2} activated and Mg^{+2} activated ATPase activity of this fraction did not change in parallel with loss in gel strength of surimi prepared from the same lots of fish.

Ca^{+2} - ATPase activity of actomyosin extracted from cod held on ice for up to 21 days declined rapdily during the late stages of storage but did not appear to be a sensitive indicator of actomyosin denaturation as judged by viscosity (Figures 13B and 14B). The data indicate that Ca^{+2} - ATPase of extracted actomyosin is not a sensitive indicator of gel strength potential.

The Ca^{+2} activated and Mg^{+2} - ATPase activity of glycerinated cod muscle was also measured and these results suggested a close parallel between actomyosin viscosity and the ratio of Ca/Mg ATPase activity during 8 days storage of cod on ice (Figure 15B).

The Ca^{+2} activated ATPase activity of untreated and intact muscle sections from bled cod stored for up to 9 days on ice showed a high correlation with actomyosin viscosity ($r^2 = 0.995$). During storage of bled cod for up to 9 days the viscosity of actomyosin declined gradually from about 24 cps to about 16 cps and Ca^{+2} activated ATPase activity declined from 9.52 and 2.32 umoles Pi/min - g tissue (Figure 13A). However, during subsequent storage of cod from 9 to 21 days, the apparent viscosity of actomyosin decreased more rapidly, from 16 to 3 cps while the Ca^{+2} activated ATPase activity increased from 2.32 to 7.83 umoles Pi/min - g tissue. Regression analysis of apparent viscosity as a function of ATPase over 21 days storage gave an $r^2 = 0.002$.

The pattern of whole tissue Mg^{+2} - ATPase over 21 days storage was similar to that of Ca^{+2} - ATPase, although it did not correlate with viscosity as well as Ca^{+2} - ATPase during 9 days storage ($r^2 = 0.504$) it correlated better than 21 days storage ($r^2 = 0.327$).

Multiple regression analysis with viscosity as the dependent variable and Ca^{+2} - ATPase and Mg^{+2} - ATPase as independent variables for 9 days or 21 days gave better fits, $r^2 = 0.998$ and 0.422 respectively.

These data indicate Ca^{+2} - ATPase activity may be a sensitive early indicator of myosin denaturation during the storage of bled cod on ice.

A study to determine the relationship between whole tissue ATPase and actomyosin viscosity during storage of unbled cod on ice is summarized in Figure 14A. The results indicate a similar, although more stable, pattern of ATPase activity change during storage. The earlier decline in actomyosin viscosity seen with bled cod (after 6 days, Figure 14) in contrast to unbled cod (after 13 days, Figure 13) did not appear to be associated with a more rapid initial decline in ATPase activity. As a result, the good correlation between actomyosin viscosity and muscle ATPase observed for bled cod may be more coincidental rather than based on a direct relationship to actomyosin denaturation.

A preliminary study was determined to test an ATPase method with a surface electrode on an intact fillet by pH shift. The results indicate a time dependent decline in pH after addition of ATP (Figure 16). A method like this may be amenable to dockside grading.

Thermal stability of cod actomyosin - Preincubation of cod actomyosin at various temperatures prior to measurement of viscosity at 5°C indicated the temperature at which denaturation occurs, as evidenced by a marked decline in viscosity, decreased with post-mortem storage time of the raw material. For example, for actomyosin from fresh cod, the denaturation temperature is about 20°C while it is about 10°C for actomyosin from cod held on ice for 8 days (Figure 17). This finding may indicate that temperature control during surimi processing of raw material which is less than very fresh may be very important.

CONCLUSIONS

1. Atlantic cod is a very durable raw material for surimi processing. It is possible to prepare a good yield of "AA" kamaboko from surimi prepared by laboratory procedures from bled summer cod held on ice for up to 7 days and from bled winter cod held on ice for up to 12 days. it will be important to verify these results with pilot scale lots of cod since the ability to dewater and the yield of surimi from aged raw material may be much lower under commercial or pilot scale conditions of dewatering.

2. Cod fillet held at 0 ± 0.2°C makes better quality surimi than cod held at -3 ± 1°C. It is likely the oppposite results would be obtained with better temperature control at -3°C using partial freezing chambers now commercially available in Japan.

3. Cod which were bled prior to storage of their fillets at 0°C maintain better quality (approximately 50% longer) for surimi production than cod which were not bled. These observations are interesting and may be of practical importance, but they will need to be investigated by holding bled and unbled round or dressed cod on ice for various times prior to preparation of surimi with the pilot line.

4. The apparent viscosity of a simple actomyosin extract from cod muscle or surimi is a sensitive indicator of kamaboko making potential of cod surimi. While there is some indication that Ca^{+2} - ATPase of whole muscle is an indicator of surimi gel strength potential the data are quite complex and, at this time, ATPase does not appear to be a promising predictor of gel strength potential. Additional research may show that under appropriate conditions of assay, ATPase can be used as a predictor of surimi quality.

5. Proteolytic hydrolysis of cod muscle proteins does not appear to play a significant direct role in loss in gel strength potential. There appears to be a decrease in the molecular size of myosin and major changes occur in other minor muscle proteins. The possibility that proteolysis is indirectly involved with the loss in gel strength potential cannot be ruled out at this time. However, the loss in actomyosin viscosity which is associated with the loss in gel strength potential appears to be directly related to aggregation of these proteins.

TABLE 1. Influence of Acclimation Temperature Prior to Sacrifice of the Chemical Composition of Muscle.

Tank Temp	Moisture	Ash	Crude Prot	Extract Prot	Free A.A.	TMAO
°C	%	%	%	%	mg%	mg%
10	81.36±.57 [a]	1.26±.09 [a]	16.20±.79 [a]	9.71±.21 [a]	340 [a]	416 [a]
0	81.03±.22 [b]	1.40±.03 [a]	18.70±.62 [a]	12.70±.45 [a]	500 [a]	415 [b]
12(July) [2]	–	–	16.88±.59 [b]	9.87±.46 [b]	–	–
2[2](Feb)	–	–	18.25±.86 [b]	13.20±.58 [b]	–	–

[1] Average of four determinations, except TMAO is average of two determinations. Values in column followed by same letter are significantly different($P<0.05$).

[2] Ambient sea water temperature: 12°C in July and −2°C in February

FIGURE 1. **Fillet Storage Time vs Fold Test**

"Commercial" Atlantic Cod

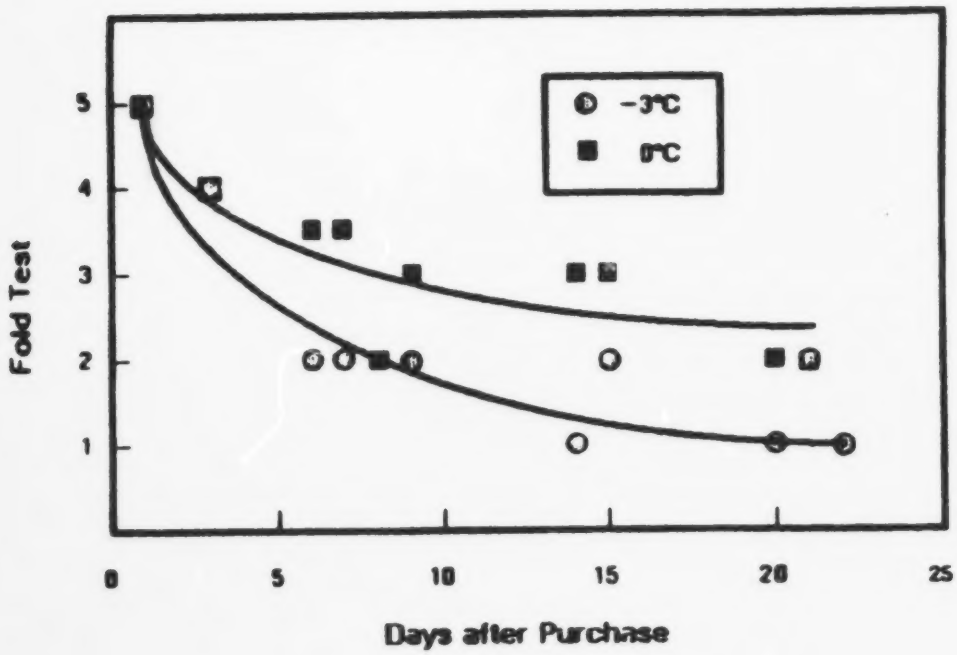
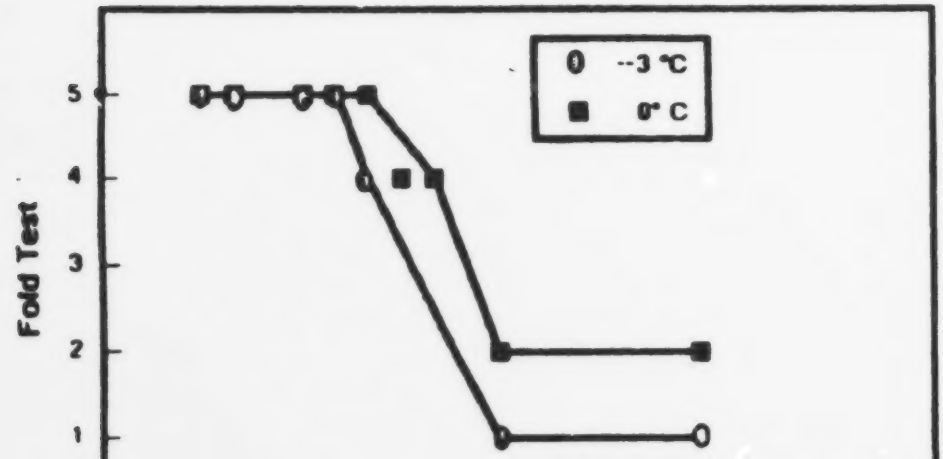


FIGURE 2. **Fillet Storage Time vs Fold Test**

Tank Fish, Bled & Iced at Harvest



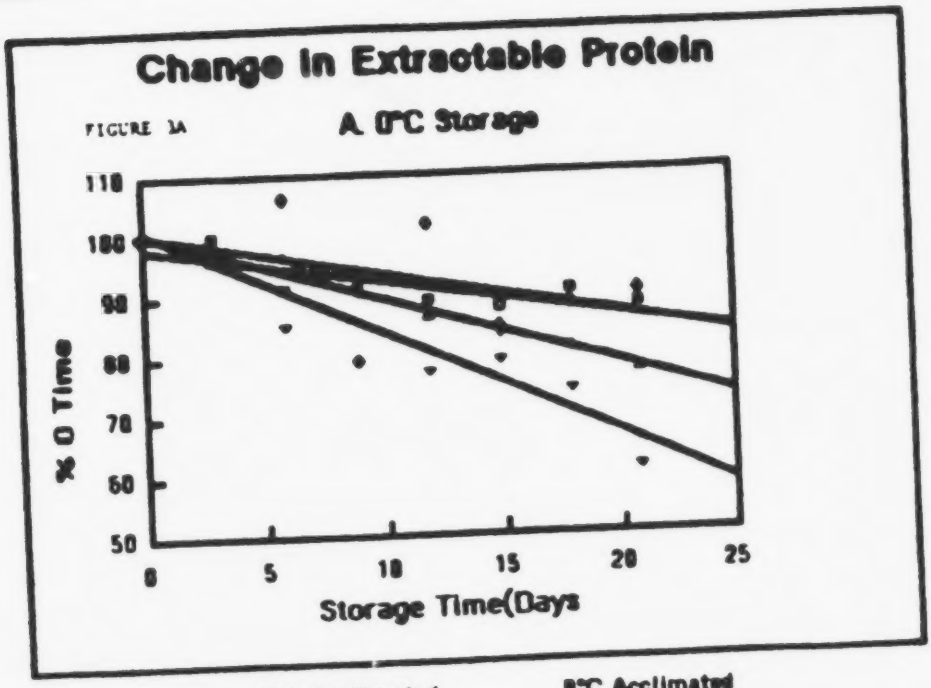


FIGURE 3A

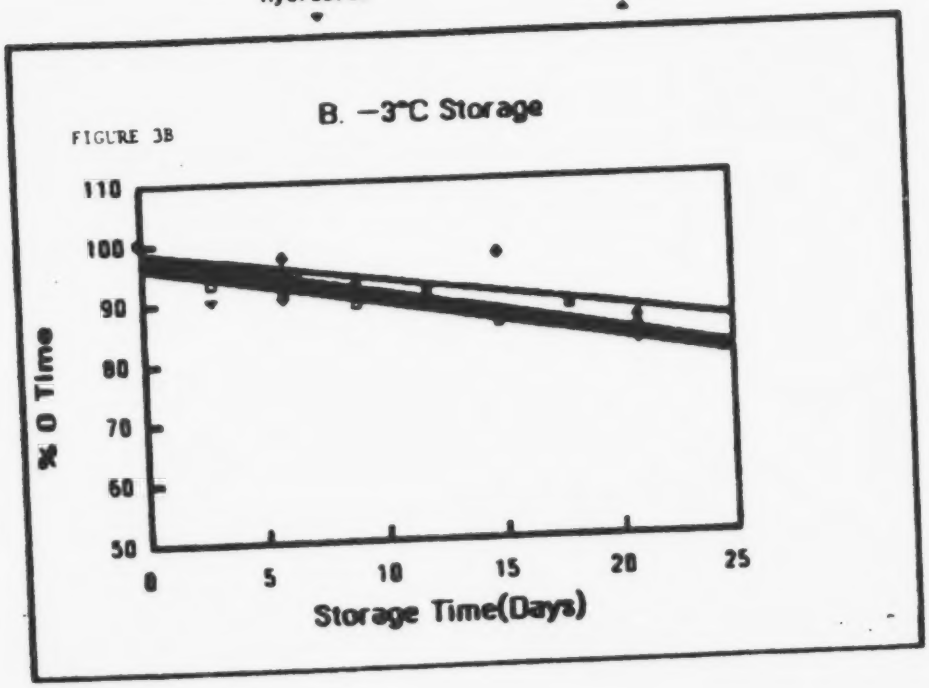


FIGURE 3B

FIGURE 4A.

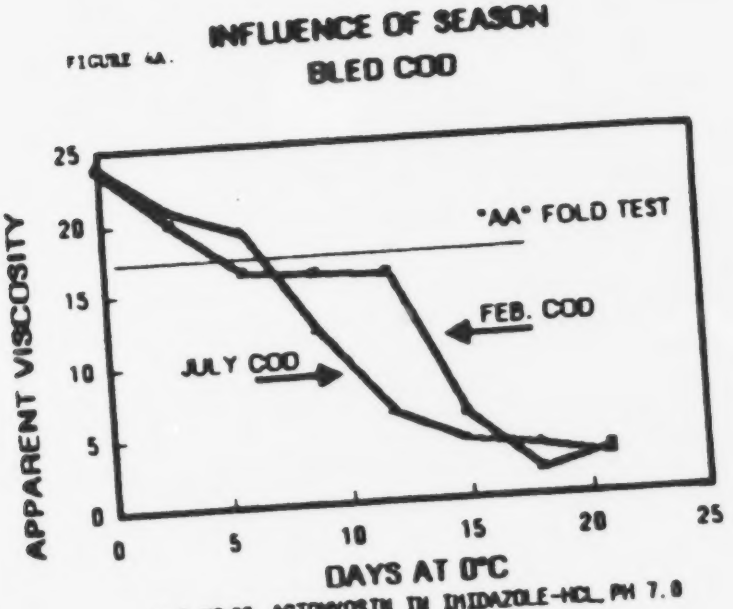


FIGURE 4B.

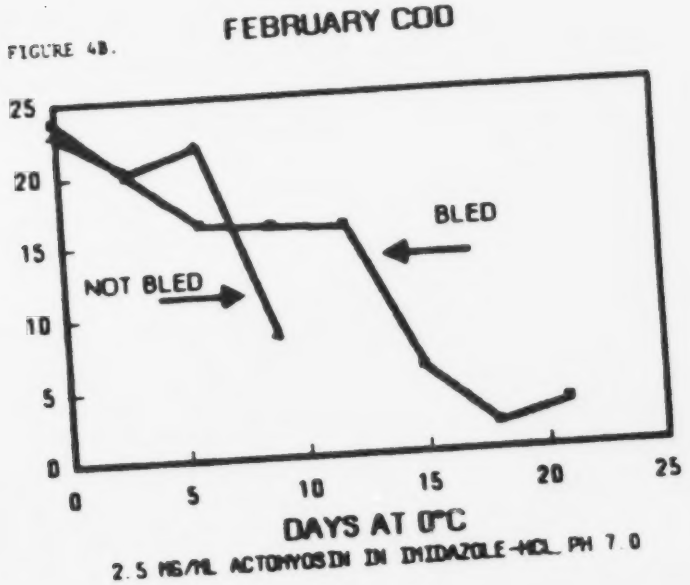


FIGURE 5. **Fillet Storage Time vs Fold Test**

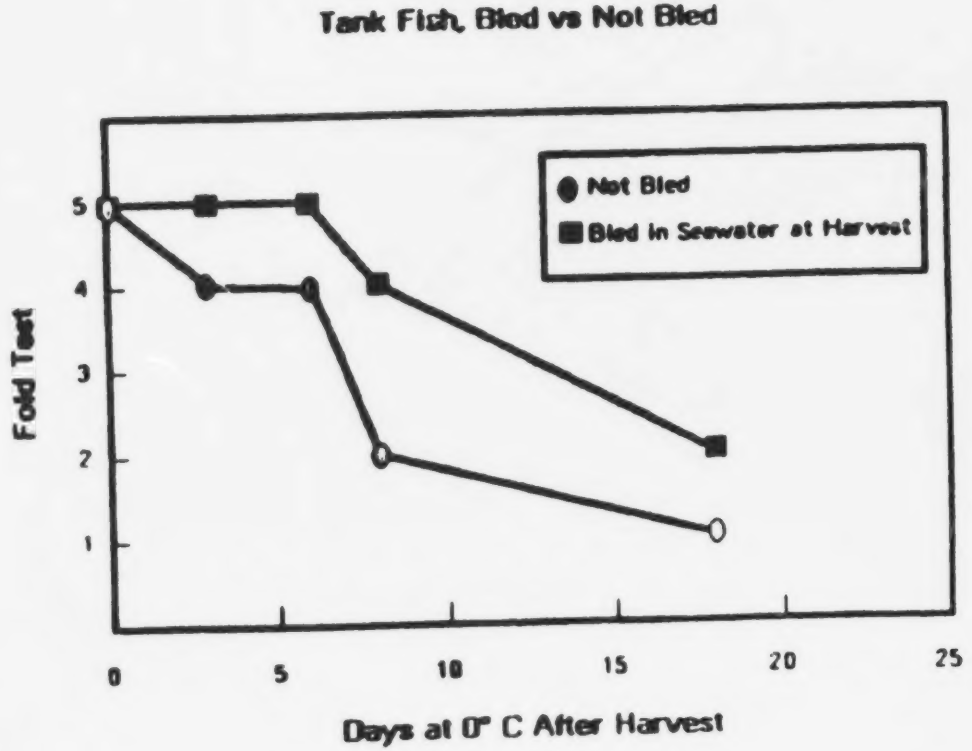


FIGURE 6. **Actomyosin Viscosity vs Fold Test**

Surimi from Atlantic Cod of Varying Postmortem Age

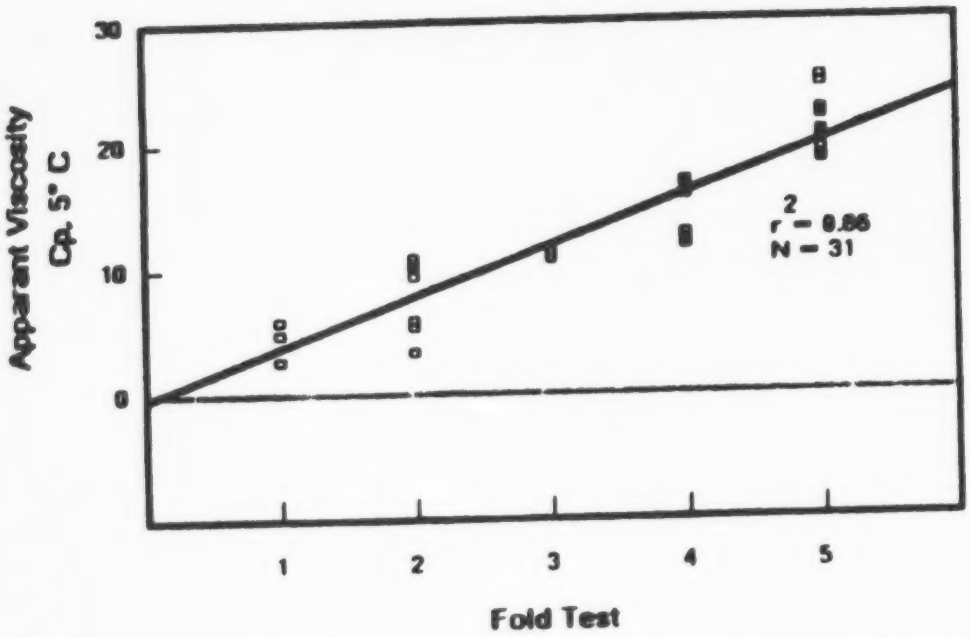


FIGURE 7.

Actomyosin Viscosity & Fold Test vs Fillet Storage

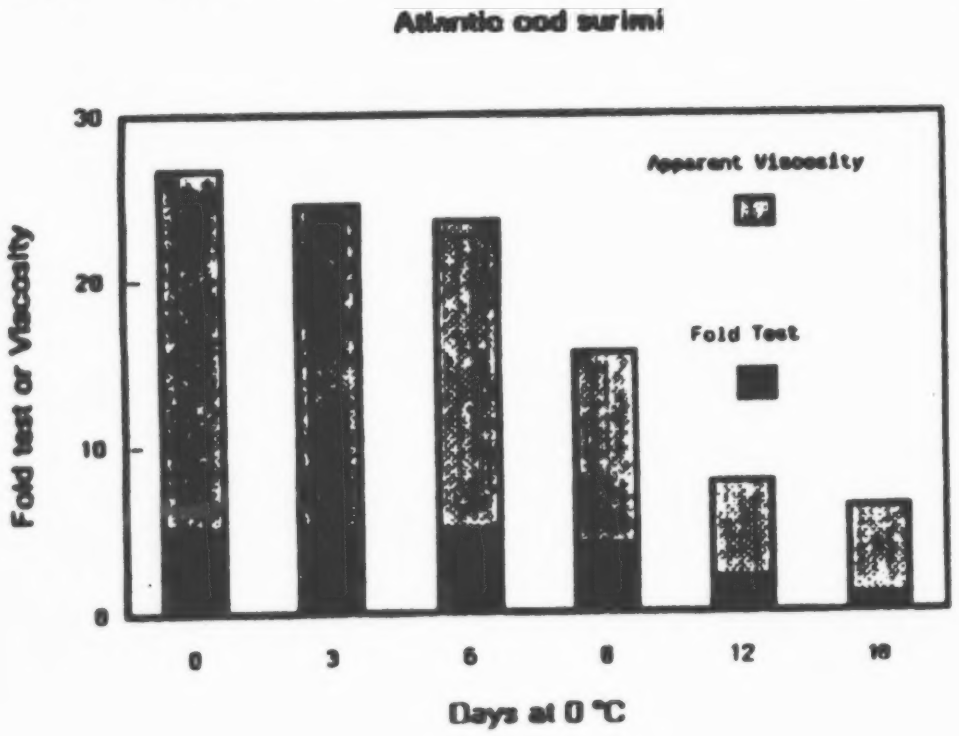
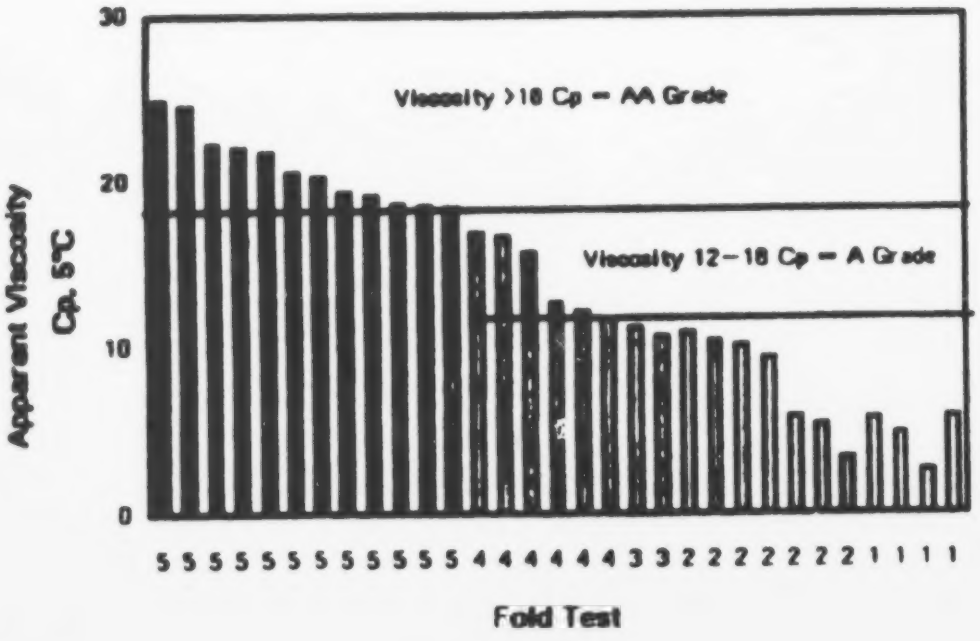


FIGURE 8.

Actomyosin Viscosity vs Kamaboko Fold Test

Surimi from Atlantic Cod of Varying Postmortem Age


Apparent Viscosity
Cp. 5°C
30
20
10
0
Viscosity >18 Cp — AA Grade
Viscosity 12–18 Cp — A Grade
5 5 5 5 5 5 5 5 5 5 5 5 4 4 4 4 4 4 3 3 2 2 2 2 2 2 2 1 1 1 1
Fold Test

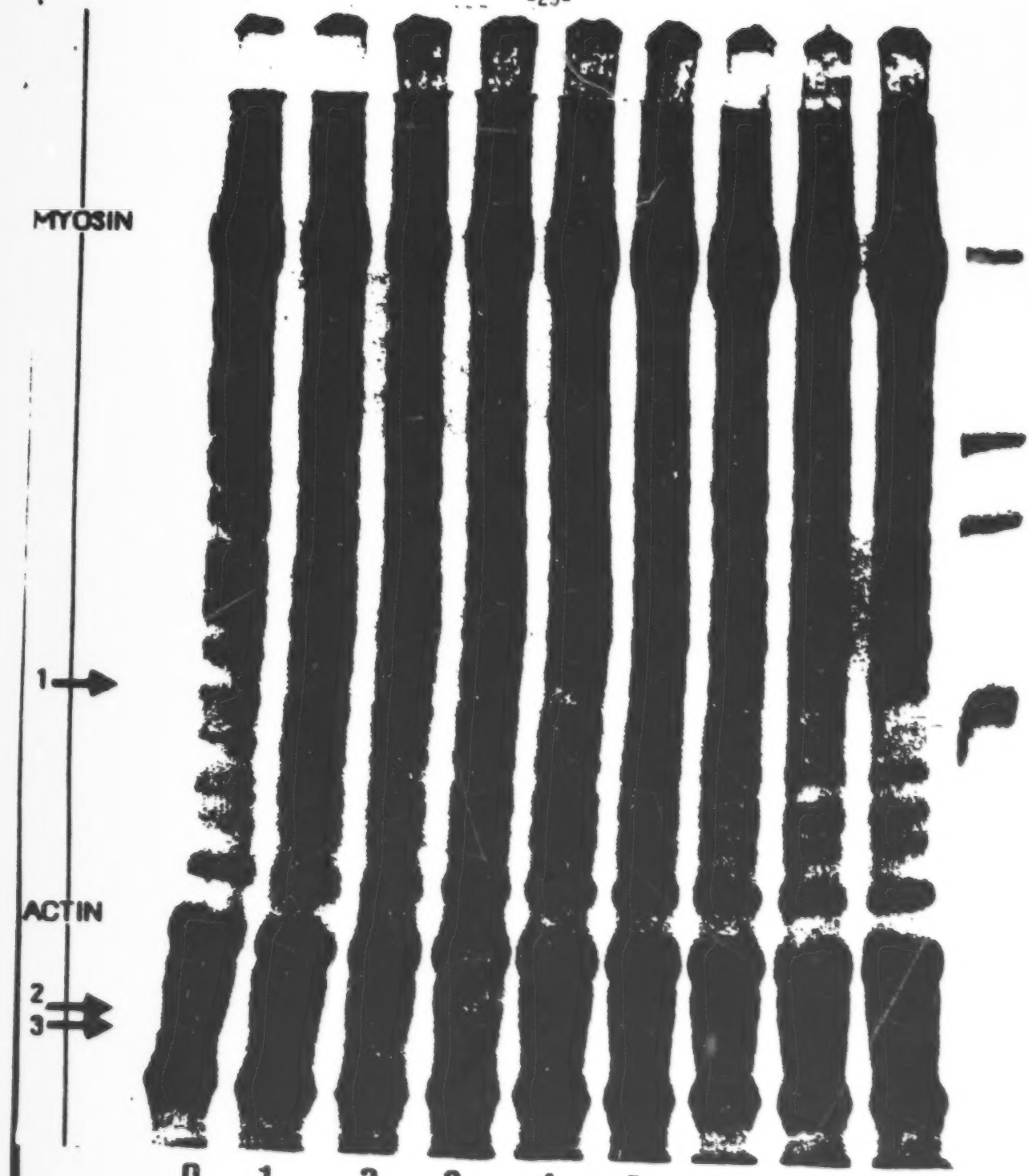


Fig. 9

ATLANTIC COD, BLED

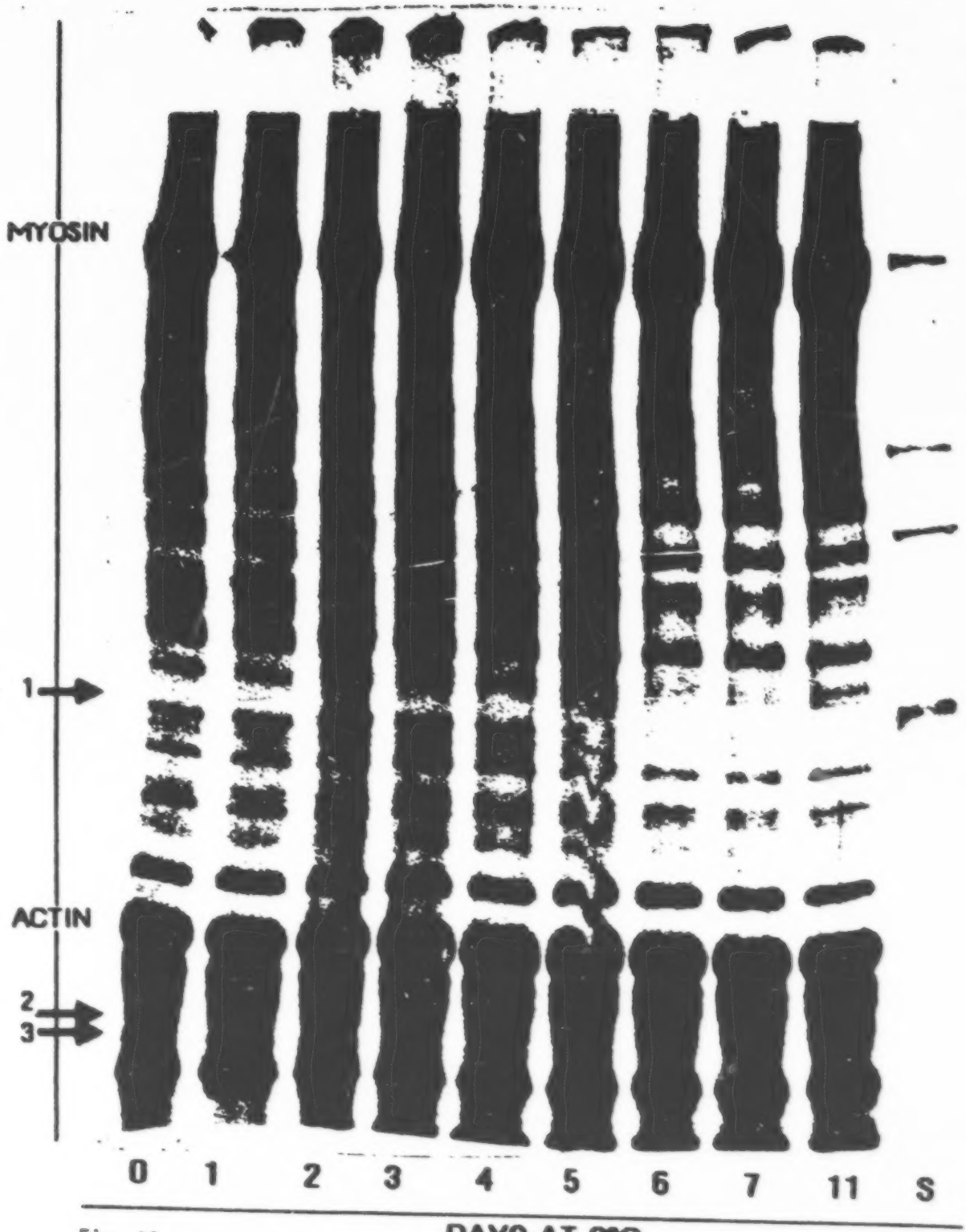
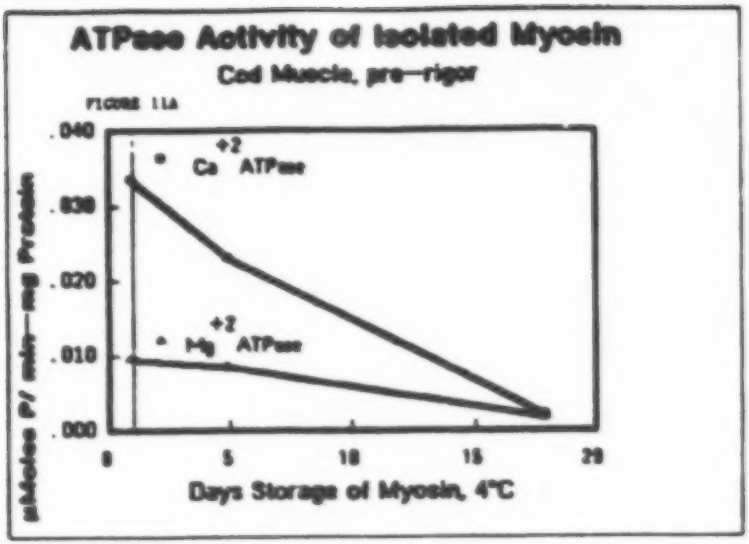


Fig. 10

ATLANTIC COD, NOT BLED


ATPase Activity of Isolated Myosin
Cod Muscle, pre-rigor
FIGURE 11A
.040
.030
.020
.010
.000
μMoles P/ min-mg Protein
+2
Ca ATPase
+2
Mg ATPase
0
5
10
15
20
Days Storage of Myosin, 4°C

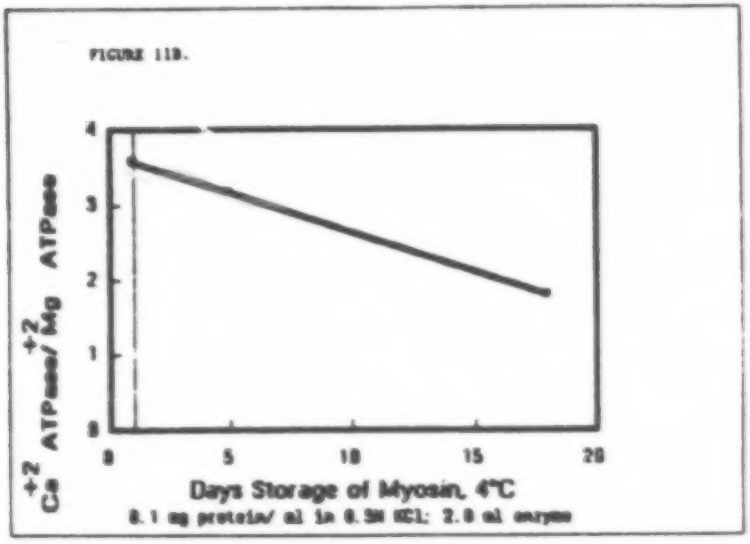
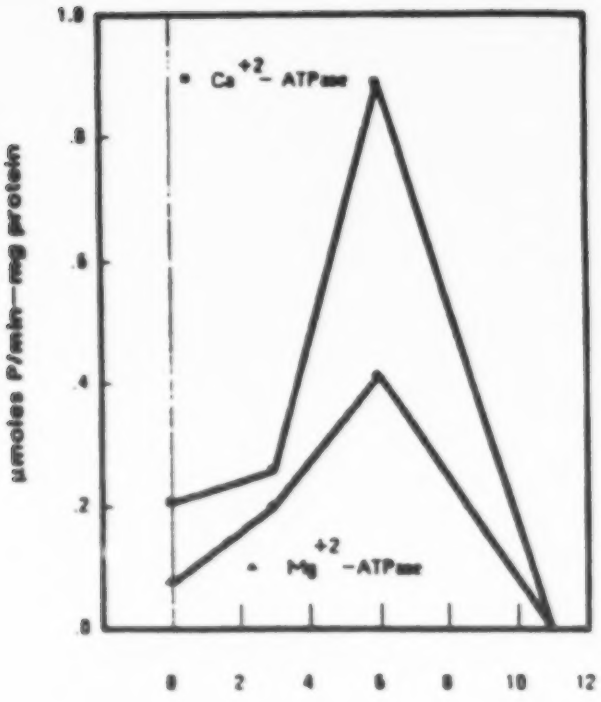


FIGURE 11B.
4
3
2
1
0
+2 +2
Ca ATPase/ Mg ATPase
0
5
10
15
20
Days Storage of Myosin, 4°C

FIGURE 12. **Sarcoplasmic ATPase**

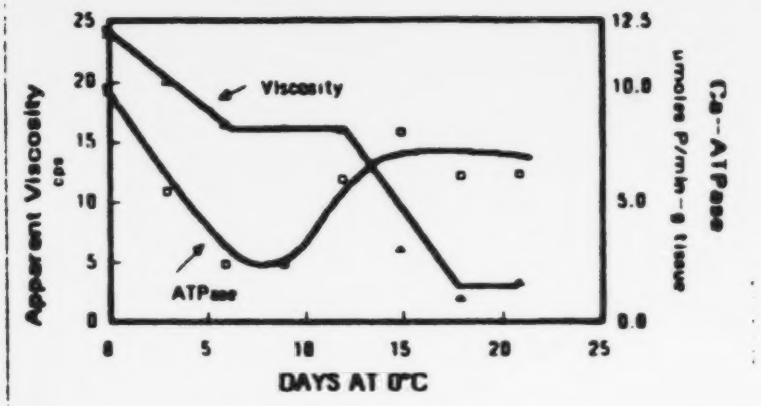
Glycerinated Muscle



Bled Cod

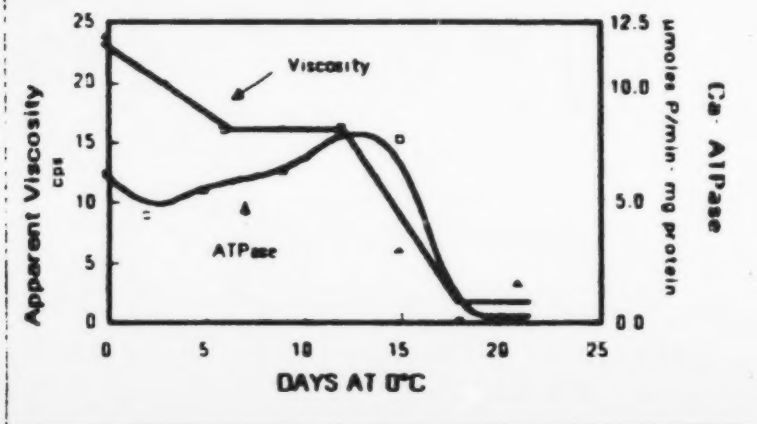
Actomyosin Viscosity vs Muscle ATPase

FIGURE 13A. BLED COD



Actomyosin Viscosity vs Actomyosin ATPase

FIGURE 13B. BLED COD



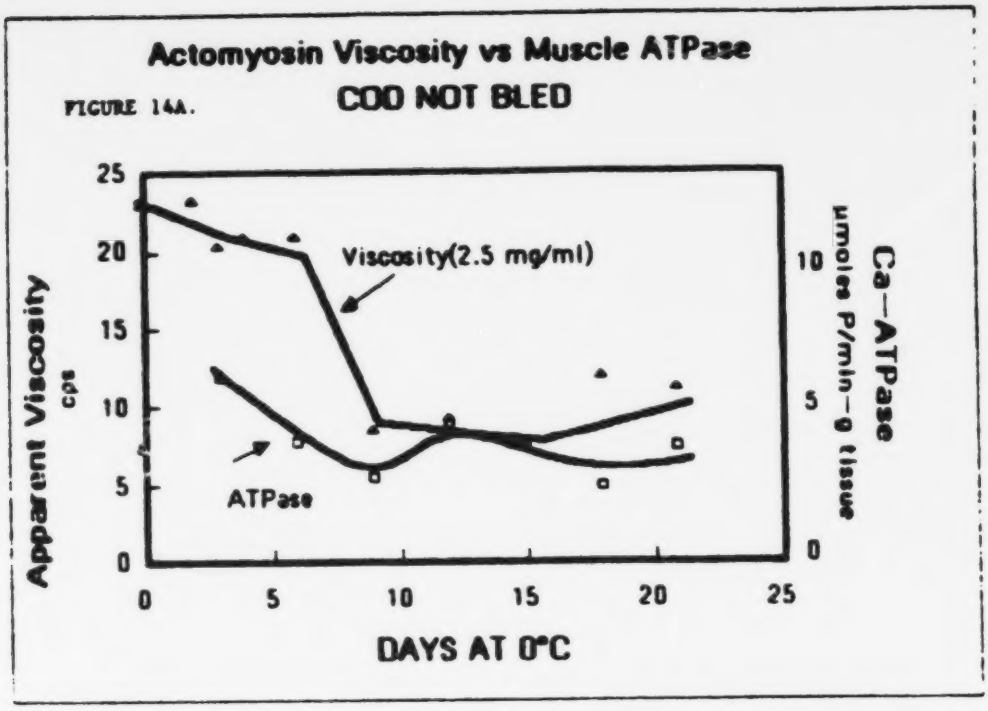


FIGURE 14A.

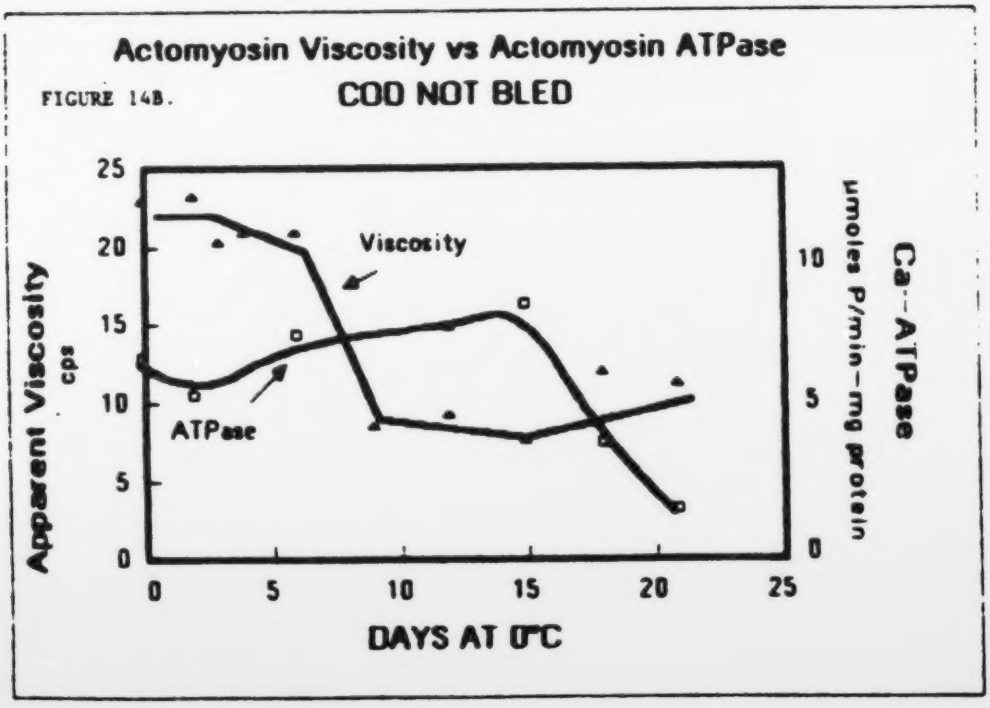


FIGURE 14B.

FIGURE 15A.

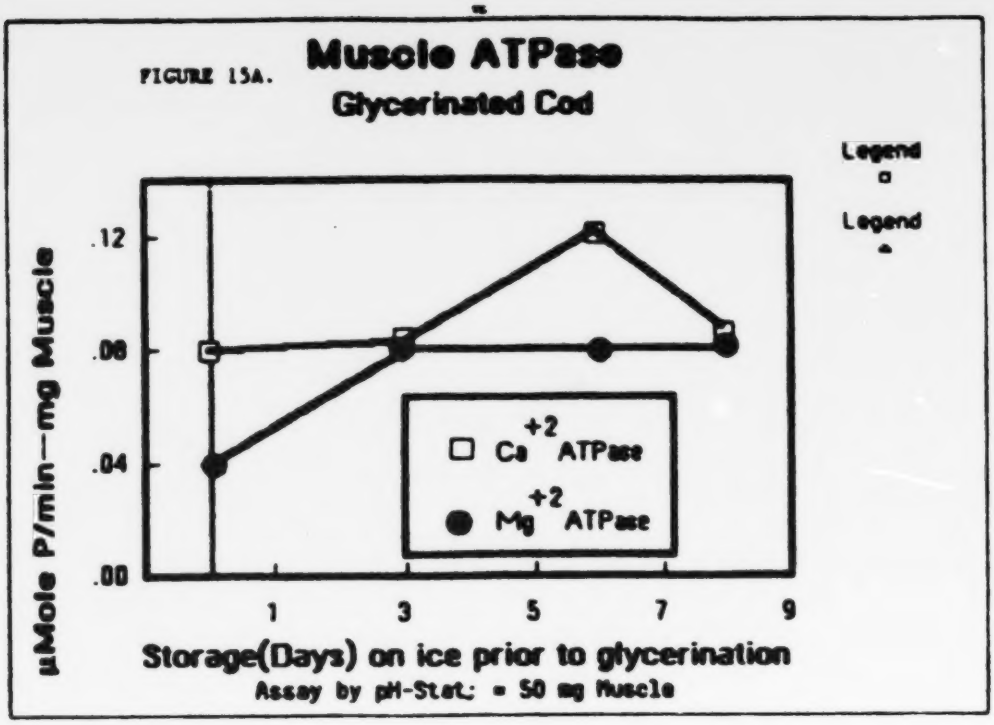
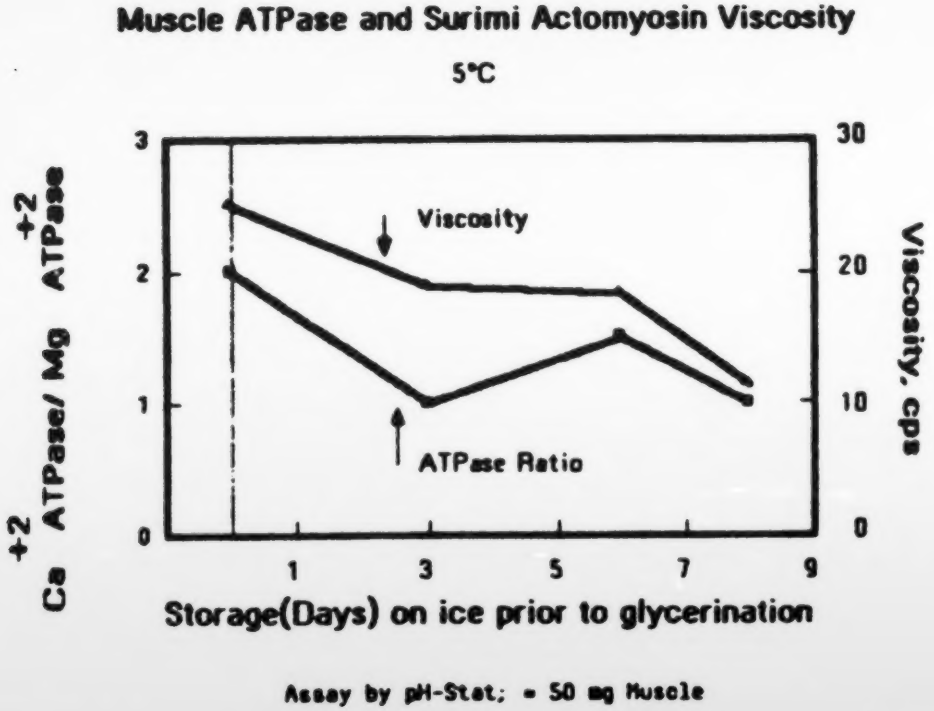


FIGURE 15B.



Assay of Muscle ATPase with a Surface Electrode

FIGURE 16.

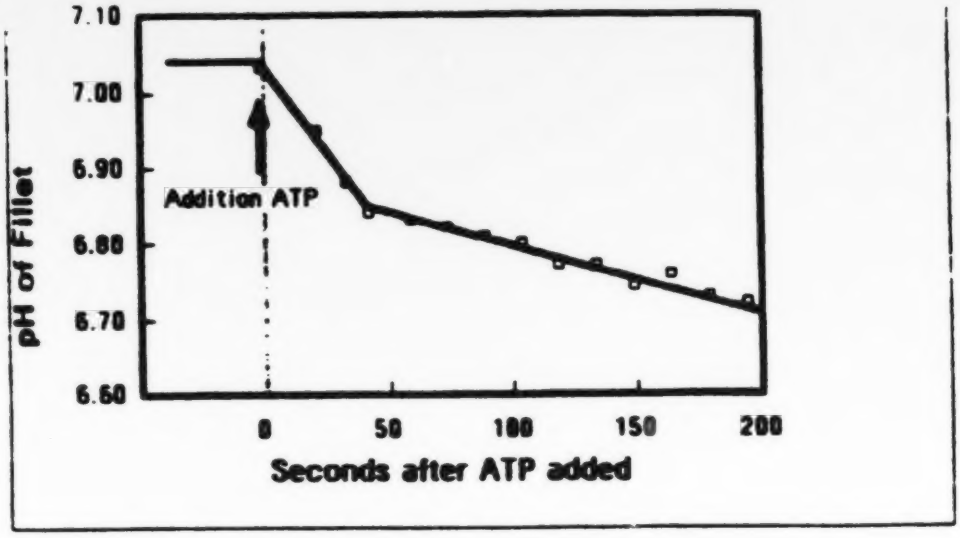
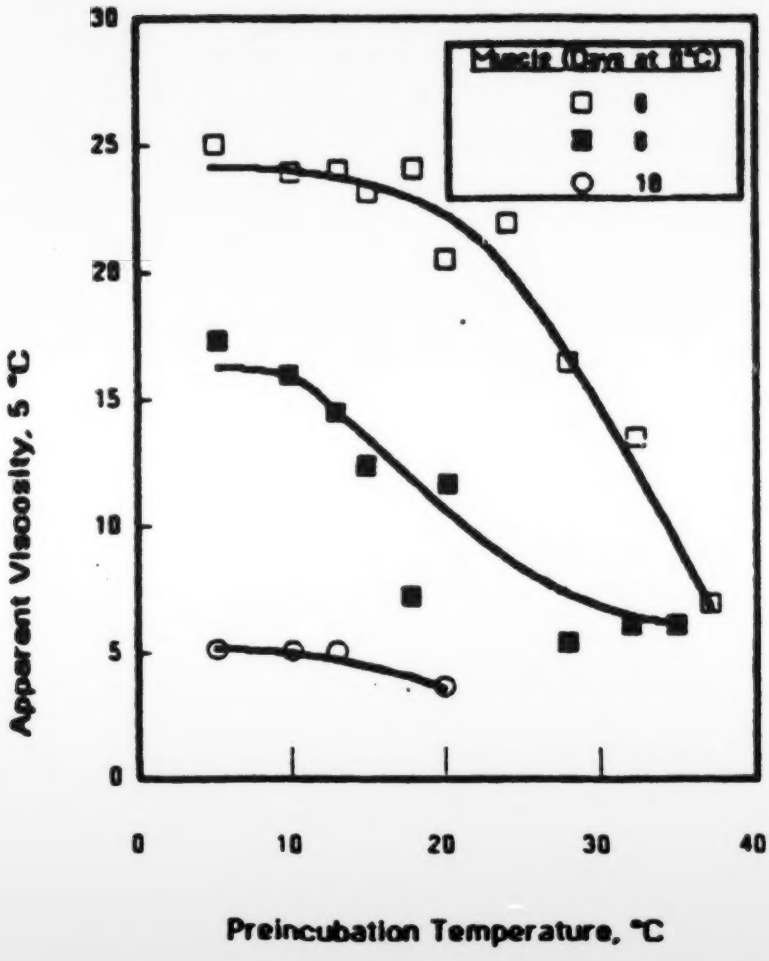


FIGURE 17.

Thermal Instability of Surimi Actomyosin



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PART

3

A STUDY OF THE USE OF COD, COD BY-PRODUCTS AND CRUSTACEAN BY-PRODUCTS FOR SURIMI AND SURIMI-BASED PRODUCTS: PART III - SHELLFISH FLAVOUR EXTRACTION STUDIES

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Fisheries and Aquatic Sciences No. 177

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by

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ABSTRACT

Voigt, M.N. August 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part III - Shellfish Flavour Extraction Studies. Can. Ind. Rep. Fish. Aquat. Sci. 177: vii + 42 p.

Eleven of twelve identified taste-active components have been analyzed from crab and scallop wastes and commercially produced flavourants. Crab cooker water and crab leg shells and tip shells have been identified as good potential sources for flavour extracts. The rate of accumulation of flavour components in cooker water decreased after 2 hours of processing. Except for adenosine monophosphate, scallop offal and adductor muscle have equal contents of flavour-active components. Green pigment in scallop wastes constitutes a problem. A scallop-flavoured kamaboko product has been successfully developed. An extruder for texturizing kamaboko has been developed for producing scallop and crab-flavoured analogues on a laboratory scale.

RÉSUMÉ

Voigt, M.N. August 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part III - Shellfish Flavour Extraction Studies. Can. Ind. Rep. Fish. Aquat. Sci. 177: vii + 42 p.

On a analysé onze des douze composantes gustatives identifiées dans les déchets de pétoncle et de crabe et les assaisonnements commerciaux. L'eau de cuisson du crabe ainsi que les coquilles des pattes et l'avant de la carapace ont été reconnues comme de bonnes sources potentielles d'extraits de saveur. Le taux d'accumulation des composantes gustatives dans l'eau de cuisson a diminué après 2 h de traitement. Sauf pour le monophosphate d'adénosine, les issues et le muscle adducteur du pétoncle contiennent la même teneur en composantes gustatives. Le pigment vert retrouvé dans les issues de pétoncle constitue un problème. Du kamaboko à saveur de pétoncle ainsi qu'une boudineuse pour la texturation du kamaboko ont été mis au point. Celle-ci servira à la fabrication expérimentale d'analogues à saveur de pétoncle et de crabe.

PREFACE

A contract was awarded to a research team from the Newfoundland and Labrador Institute of Fisheries and Marine Technology (The Marine Institute) and Memorial University to study the potential of selected Canadian Atlantic fish species and shellfish processing wastes to produce surimi and shellfish flavours. Research to develop methodology for rapidly determining the potential of raw materials to produce surimi was initiated, objective laboratory techniques for evaluating the quality of surimi were established, a pilot line for producing surimi was installed, surimi was produced from cod and other groundfish. Some biochemical indices of cod were analyzed under various conditions of storage and methods were established which may assist as predictors of surimi potential from cod and possibly other species. Crab process wastes and scallop process wastes were analyzed for their contents of flavour-active components. Methods of concentrating flavours were identified.

Three separate publications from this contract were issued. Correct citation for these are:

Chandra, C.V. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part I - Raw Material Assessment.

Haard, N. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part II - Physiology Studies.

Voigt, M.N. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part III - Shellfish Flavour Extraction Studies.

The opinions and interpretations expressed in the report are those of the author, and do not necessarily reflect those of the Department of Fisheries and Oceans.

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INTRODUCTION

American sales of surimi, mainly for preparation of shellfish analogues, have risen in five years from about two million to about three hundred million dollars in 1985 (Katayama, Pers. Comm.). The latter figure represents about 34.5 million kgs. (76 million lbs.) of products, with crab-flavoured surimi-based analogues accounting for more than eighty percent of the total (Katayama, Pers. Comm.). It is forecast that North American consumption of surimi-based products will rise to over three billion dollars worth in the early 1990's, and that market will include a variety of shellfish analogues (Anon. 1985); (Harris, 1984).

The North American supply of natural and surimi-based crab combined grew from 22.7 million kgs. (50 million lbs.) (meat weight) in 1974 to 63.5 million kgs. (140 million lbs.) in 1984 (Vondruska, 1985). Thirty million kgs.(66 million lbs.) of the increase was due to the introduction of the crab analogue. The yield of meat from the shellfish is relatively low, ie. about 30 percent from snow crab, 12 percent from the Giant scallop and 36 percent from the Icelandic scallop. As a result, large quantities of offal are produced. Processing of snow crab and scallop produced more than 24,000 and 70,000 tonnes respectively. In Atlantic Canada, the offal from shellfish processing is not utilized at this time, thus causing environmental and disposal problems. Shellfish wastes contain significant amounts of compounds responsible for flavour.

Recently, a process based on chelation and specific enzymic catalysis has been developed in Newfoundland for extraction of carotenoprotein and flavour components from shrimp offal (Simpson and Haard, 1985). Additional study is needed to determine the suitability of this process for recovering crab essence. A Canadian patent (No. 210795) has been filed by United Maritime Fisherman (Moncton, N.B.) for an enzymic process to extract flavourant from lobster shells with spray drying being used to produce a powder. It is recognized that the taste of protein hydrolyzates is influenced by the type and degree of protein hydrolysis (Godfrey and Reichelt, 1983), and this factor will be an important consideration in developing a method for recovering flavour essence from crustacean process offal. In this regard, it is known that a proteolytic enzymic preparation from the hepatopancreas of Atlantic short finned squid has been shown to promote the formation of a brothy, meaty flavour when used as a supplement to fermentation of squid (Lee et al., 1982) and to fish sauce prepared from capelin (Raksakulthai et al., 1986). The active enzyme appears to be cathepsin C (Hameed and Haard, 1985).

Flavourants for the processing of shellfish analogues in North America are currently imported from Japan. Costs for the flavourants in 1986 are 40 percent higher than in 1985 (personal communication with Dr. C. Ho, Terra Nova Fisheries, March 26, 1986). The primary objective of the shellfish flavourant research during the first contract period was to determine the suitability of crab offal as a raw material for production of a natural crab flavourant. Preliminary work was initiated on texturizing surimi/kamaboko analogues, and also on flavouring the texturized kamaboko with crab and scallop.

MATERIALS AND METHODS

COLLECTION OF SAMPLES

Samples from the processing line for male snow crab, **Chionoecetes opilio** were collected four times during the processing season with at least one week intervals between samplings. The following types of samples were collected: waste fluids (butchering, cooking, cooling, shoulder shell washer, leg roller exudate, tip roller exudate), shells (tips and legs, shoulders) and meat (tip, leg, shoulder). Live Icelandic scallops, **Chlamys islandicus,** were collected on the St. Pierre Bank in October, 1985. After shucking, the adductor muscle was packaged separately from the viscera and mantle in heat sealed 4.5 mm polyester film pouches (Kopak Corp., St. Louis, Minn.). All samples were stored at -20°C. Extractions were normally completed on the samples within one week of collection.

PREPARATION OF TEST MATERIALS

The taste-active components present in the samples of crab and scallop were prepared using a modified version of a method described by Konosu et al., 1978). The modifications were as follows:

a) Liquids: Strained through 1 mm^2 stainless steel wire mesh; 150 ml of sample placed in one litre Erlenmeyer flask; heated in a boiling water bath for 15 minutes; cooled in an ice bath; 600 ml absolute ethanol added; stirred; let stand for 15 minutes; filtered through Whatman No. 1 filter paper with suction; filtrate washed twice with 25 ml aliquots of 80 percent ethanol; filter residues discarded; filtrates

combined and evaporated to 150 ml under vacuum at 40°C. For sensory evaluation, the filtrates were brought to dryness under vacuum at 60°C and then reconstituted with water.

b) Shells: 100 g of shells combined with 100 ml of water and mascerated for 2 minutes in a Waring Blender; cooled in an ice bath; centrifuged at 15,000 rpm for 15 minutes; supernatant decanted into a 250 ml graduated cylinder; precipitate washed twice with 20 ml of water, all of the supernatants combined; volume brought to 150 ml with water; and then proceeded using the procedure described for broths.

c) Meats: 30 g of meat combined with 50 ml of water; mascerated for two minutes in a Waring Blender; heated in a boiling water bath for 15 minutes; supernatant decanted into a 100 ml graduate cylinder; precipitate washed twice with 20 ml water; all of the supernatants combined; the volume brought to 100 ml with water and transferred to a one litre Erlenmeyer flask; added 400 ml absolute ethanol with stirring let stand for 15 minutes, filtered through Whatman No. 1 filter paper with suction and washed twice with 25 ml aliquots of 80% ethanol; the filtrates combined and evaporated to 100 ml under vacuum at 40°C.

All extracts were stored frozen at -20°C.

CONTENTS OF SHELL

Ten millilitre aliquots of liquid samples were filtered through Whatman No. 1 filter paper. The filter paper that contained the insoluble residue, as well as the filtrate that contained the soluble solids were dried under vacuum at 40°C for 16 to 24 hours.

FREE-AMINO ACIDS

One ml of the extracts from the liquids, shells and meats were diluted with 9 ml of 0.1 M hydrochloric acid. Twenty mg of commercial crab flavourants were diluted to 10 ml with lithium citrate buffer (pH 2.2, 0.2N, containing 1% thiodiglycol and 1% phenol; Pierce Chemical Co., Rockford, Ill).). Samples were deproteinized with 10% sulfosalicylic acid (SSA; four parts of sample to one part SSA) and diluted 1:2 with lithium citrate buffer. Deproteinized samples were analyzed on a Beckman 121 MB Amino Acid Analyzer using Benson D-X8.25 resin (Benson Co., Reno, Nevada) in a single column and using the three buffer lithium method for physiological fluid analysis as per Beckman 121 MB-TB-017 application notes (1979, Beckman Instruments Inc., Palo Alto, CA).

INORGANIC IONS

The contents of sodium, potassium, chloride and phosphate (PO_4^{3-}) in the extracts were determined by using ion specific electrodes (Beckman Astra-8 for sodium, potassium and chloride but the Hitachi-705 Boehringer Mannheim Canada Ltd., Dorval, PQ for phospate). The results were confirmed using the Technicon Autoanalyzer II (Technical Canada Inc., Montreal, P.Q.) for chloride (ferricyanide/thiocyanate, Naquadat No. 17206) and phosphate (ammonium molybdate, Naquadat No. 15406). However, atomic absorption spectrometry (AA; Varian Canada Inc., Georgetown, Ont.) was used for sodium (Naquadat No. 11105) and potassium. For the Technicon and AA analyses, ca 0.2 g of samples were placed in 10 ml of 50% ultrapure nitric acid (Seastar Chemicals, Sydney, B.C.) and left for one hour. The samples were heated

gently without being allowed to dry for two hours, the volumes were adjusted to 100 ml with Type One water (Barnstead Nanopure Ion Exchange System, Barnstead Company, Pickering, Ont.), and then the samples were analyzed using the application notes cited above.

NUCLEOTIDES

A reverse phase High Pressure Liquid Chromotography (HPLC) procedure was used for the analyses of nucleotides. The chromotograph was a Waters (Water Associates, Inc., Milford, MA) equipped with two solvent delivery pumps (Model 6000A), solvent programmer (Model 660) and a universal injector (Model U6K). A fixed wavelength detector (Model 440) monitored the effluent at 254 nanometer. A HP 3390 integrator (Hewlett Packard Ltd., Mississauga, Ont.) was used for the calculation of peak areas and retention times. A micro Bondapak TM C18 stainless steel column (3.9 mm I.D. x 30 cm. Waters No. 27324) was employed for the separations. The buffer (0.05M sodium dihydrogen orthophosphate, Analar grade, BDH Chemicals, Toronto, Ont.) was prepared fresh every second day in double distilled water, adjusted to pH 4.70 with 1.0 M phosphoric acid (Reagent grade, Caledon Laboratories, Georgetown, Ont.) or 1.0 M sodium hydroxide and filtered through a 0.45 micrometer Millipore filter disc (Millipore Ltd., Mississauga, Ont.). The standards were dissolved in double distilled water and diluted to desired concentrations (ca 25ug/ml). Adenosine, cytidine, guanosine, uridine and their mono, di and triphosphates were purchased from Sigma Chemical Co. (Kit No. K100-25A; St. Louis, Mo.). Other standards were inosine monophosphate (Boehringer Mannheim Ltd., Dorval, P.Q.)

inosine, hypoxanthine and uric acid. All samples were homogenized before analysis. A 1 g sample was weighed into a 10 ml volumetric flask, 5 to 7 ml of 0.05 M pH 4.70 buffer was added, dissolation was assisted by ultrasonication for 10 minutes, and finally the solutions were diluted to volume. Extracts of the samples were then filtered through a 0.45 micrometer Millipore filter disc and injected into the HPLC system (5 to 40uL). The eluting program was isocratic with a flow rate of 1 ml/minute. The eluted peaks were identified by their retention times and peak areas were used for quantification.

BETAINE

Glycine betaine was determined using the sample preparation procedure by Hayashi et al. 1978 and the method of Konoso and Hayashi (1975) for separation and quantification. Five ml of the extracts prepared as described above were used for the analyses.

BREADING AND BATTER SYSTEMS

Scallop flavoured and texturized kamaboko was coated with six breading and tempura battering systems at Griffith Laboratories (Scarborough, Ont.). "Consumer" (prefried) rather than "institutional" type (un-fried) products were prepared. For the breading systems, the kamaboko was predusted with Predust 1559, battered with Kristobatter 4543 (07.2520) and then breaded with the following:

1. Kristobreading 7697 (a blend of tender homestyle and crisp Japanese style crumbs).

2. Kristobreading 8025 (low density Japanese style crumbs).
3. Kristobreading 8035 (toasted Japanese style crumbs), or
4. Kristobreading 8048 (crispy Japanese style crumbs that maintain good texture over prolonged freezer storage).

The coated kamaboko products were blanch fried for 30 sec at 199°C and stored frozen at -20°C. To reconstitute in an oven, the oven was set at 204°C and the products were baked 12 to 17 min. with turning of the products halfway through the cooking time. For the tempura battering systems, the kamaboko was predusted as previously and then battered with the following:

1. Kristobatter 4582 (a tender crisp leavened batter), or
2. Kristobatter 4584 (a crisp leavened batter).

The coated kamaboko products were blanch fried for 40 seconds at 199°C and then stored frozen at -20°C. The tempura products were reheated by baking for 10 to 15 minutes at 204°C with turning of the product halfway through the cooking time. The Kamaboko was tempered at 5°C before pre-dusting.

TEXTURIZATION

Uncooked crab-flavoured kamaboko was obtained from Terra Nova Fisheries and was blended with 10% homogenized scallop adductor muscle plus 2% Instant clear gel (pregelatinized corn starch, Griffith Laboratories, Scarborough, Ont.). The kamaboko was texturized by extrusion through a die system that produced a product that had a uniform skin on the surface and a

fibrous texture on the interior. After extrusion, the texture of the kamaboko was set by passing the product through a steam tunnel for 20 minutes and cooking in a humidified oven at 90°C for 20 minutes.

TASTE

Vocabulary for describing the taste characteristics of natural and synthetic extracts of snow crab has been developed by Hayashi et al., (1981a). Nine taste sensations were shown to be of primary importance, ie. umami (monosodium glutamate-like taste or mouth satisfying meaty taste), sweetness, saltiness, complexity, fullness, naturalness, continuance, viscosity and extension. Omission tests with synthetic crab extracts that examined the effect of omitting each of the twelve taste-active components of the synthetic extract resulted in the following findings by Hayashi et al., 1981b:

1. Omission of amino acids resulted in a decrease in sweetness, saltiness, aftertaste, body and crab-taste.
2. Omission of nucleotides weakened the characteristic crab-taste, sweetness and umami.
3. Omission of betaine resulted in declines in marine umami, sweetness and aftertaste.
4. Omission of inorganic ions markedly decreased crab-likeness, sweetness and umami, while bitterness increased slightly.

The twelve taste-active compounds that were identified by Hayashi et al. 1981b to be important for the taste of snow crab were also analyzed for in the research reported here.

An untrained panel of six experienced panelists, four females and two males ranging in age from 20 to 44, was used to evaluate the scallop-flavoured kamaboko. Panel judges were staff members, faculty and students in the Food Science Group at Memorial University of Newfoundland. Samples of the reconstituted products were assessed by preference testing using a nine point hedonic scale to evaluate colour, flavour, texture and overall acceptability as described by Larmond (1977). Statistical analyses for differences were performed by using analysis of variance with statistical significant set at $P \leq 0.05$. Least significant differences (LSD) were calculated by employing the multiple comparison method outlined by the American Society for Testing Materials (ASTM..., 1968). Only one session was conducted for the four sensory characteristics examined (colour, flavour, etc.).

For the evaluation of the extracts obtained from the processing line for crab and also for the commercial crab flavourants, the samples were presented to panelists in 250 ml beakers for the evaluation of characteristic odour. About 100 ml of the extracts obtained from the processing line for crab were brought to dryness in vacuo at 60°C in the beakers prior to evaluation. The commercial crab flavourants were evaluated as obtained. The panelists were only informed that the samples were crab extracts or flavourants and were asked to provide terminology to describe the odours of each sample. Only one session was conducted with the six panelists.

EQUIPMENT

Pilot scale reverse osmosis and swept-surface flash evaporation equipment were identified as being essential for the development of processes for concentrating shellfish flavourants.

A laboratory scale extrusion and thermal processing unit for texturizing kamabcko products was designed and built. A proposal was submitted to the Department of Fisheries and Oceans for the development and construction of an industrial scale extruder. A laboratory scale minced fish washer/de-waterer unit for the processing of surimi was also designed and built. Funding for designing and fabricating the pilot scale extruder and the minced fish washer was not provided by the DFO contract.

RESULTS AND DISCUSSION

COOKER WATER AS A SOURCE OF FLAVOURANT

Cooker water from the crab processing line was identified as being the initial source of raw material for producing a crab flavourant. Therefore, the rate of accumulation of solids (soluble and insoluble) in the cooker water from a continuous crab processor was measured (Fig. 1, App. Table 6). The rate of accumulation of solids decreased markedly after 2 hours. The concentration of solids reached a value of about 1.5% with the soluble fraction representing about half of the total. This indicates that cooker water could be continuously withdrawn after 2 hours and then either cooled and stored or fed directly into a flash evaporator. Feeding directly to a flash evaporator would have the advantage of utilizing the heat carried

with the hot liquor for partially providing the heat of vaporization for the vacuum flash evaporator.

The second option would be to transfer the cooker water from the continuous cooker at greater than 2 hour intervals to a storage tank after filtering and cooling. This approach would permit all of the cooker water to be concentrated after a critical volume has been accumulated. Disadvantages of this batch approach is the greater opportunity for thermal damage, the high energy requirements for cooling and reheating and also the need for substantial cold storage tanks. If the evaporation facility was not located within the crab processing plant, bulk storage of cooker water would be necessary.

The predicted yield of concentrated soluble solids per day (based on the 24 hour processing day at the Bay de Verde, Newfoundland plant, was calculated at 2143 L/batch x 12 batches/day x 0.75% soluble solids = 193 kg (dwb)/day. This was given an estimated value of $10 - $25/kg = $1930 to $4825/day. However, using the 1986 cost paid by a local shellfish analogue processor = 193 kg (dwb)/day x $87/kg (dwb) = $16,891/day. Assuming a 200 day crab processing season, the value of the crab flavourant would be about $386,000 to $965,000. The yields would be dramatically affected by the type of system(s) used to remove insoluble solids or to hydrolyze insoluble solids. Further treatment of shells may also contribute to increased yields.

CONTENTS OF TASTE-ACTIVE COMPONENTS

The contents of selected taste-active components and solids (soluble, insoluble and total) in samples obtained from a commercial line for processing crab are listed in Tables 1 and 2, respectively. Appendix Tables 1 and 2, respectively, provide a comprehensive report of the contents of free-amino acids (and other ninhydrin-positive substances) and of nucleotides and their metabolites in the samples obtained from the line for processing crab. The higher level of sodium in the butchering and shoulder water and also in the shoulder meat reflects the usage of seawater in these steps. In addition, the employment of seawater affected the odour of the vacuum dried residues of extracts obtained from these steps in the process (Table 9). The leg meat contained the highest concentration of the selected taste-active components.

The contents of these selected components decreased by approximately 50 percent decrements in the following order: a) in tip meat, b) in cooker water and in water collected from the tables where the tip meat was expressed from the shell, c) in water collected from the tables where the leg meat was expressed from the shell, in the shoulder meat and in the extracts from the tip/leg shell, d) in the extracts from the shoulder shell, and e) in the water used to wash the shoulder meat from the shoulder shell.

The concentrations of these components were the lowest in butchering and cooling waters. The crab cooker water and the extracts of leg meat showed the highest levels of nucleotides and their degradation products (Table 1 and App. Table 2). The shoulder meat contained markedly lower

amounts of these taste-active substances, compared to leg and tip meats, due to the large volumes of water used to separate this meat from the cavities in the shoulder shell. The same leaching effect resulted in lower contents of these substances in shoulder vs tip/leg shells.

The concentration of soluble solids present in the samples obtained from the crab processing line (Table 2) decreased from 3.3 to 0.45 percent in the following order: leg meat, tip meat, butchering water, cooker water and shoulder water (both 1.50), shoulder shell, tip/leg shell, cooler water, leg water. Thus, after considering the contents of selected taste-active components and soluble solids, the odour of the vacuum-dried residues, and the quantity of by-product raw material produced, cooker water was selected as the initial raw material for producing a natural crab flavourant. The tip/leg shells and the juices collected from the tables where the leg and tip meats were expressed from the shells also showed potential as raw materials; seawater would need to be eliminated from these processing steps, however. Enzymic or other chemical treatments would be needed to increase the yield of soluble solids from the shells.

The analyses of the selected taste-active components in the commercial crab flavourants shows that the product identified by the trade name gulesen is essentially glycine (Table 4). The ingredients entitled 'crab extracts' or 'seasoning base' contained the highest levels of these flavour-active components (Tables 3 and 4). Guanine and inosine monophosphates were the important nucleotide components present in the commercial crab flavourants (Table 3). The relative ratios of the selected flavour-active components in these crab flavourants, as well as in the

natural, will be important markers in targeting the levels of these components to be used in producing crab flavour bases from the flavour concentrates obtained from the cooker water. The author is aware of the compounds comprising the various trade-named ingredients of commercial crab flavourants; these cannot be revealed due to a secrecy agreement. The analyses completed in this research reveals the ratios of some of these compounds.

The contents of selected taste active compounds and solids (soluble, insoluble and total) in adductor muscle and offal (Visera and Mantle) of scallops are listed in Tables 5 and 6, respectively. A comprehensive listing of other ninhydrin-positive substances and nucleotides and their degradation products are listed in App. Tables 4 and 5, respectively. The results show that only adenosine monophosphate occurs at a markedly lower concentration in the offal, and thus may need to be fortified. As yet, commercial scallop flavourants have not been analyzed. A problem that needs to be solved in order to utilize the scallop offal is the presence of a dark green colour due to the ingestion of plankton by the scallops.

The analyses for the content of glycine betaine in the crab and scallop samples are incomplete. The procedure is a tedious protocol that only permits one analysis per day. However, the protocol has yielded good recoveries from spiked samples (about 97%), even though four chromotographic columns are employed.

SENSORY EVALUATION

The results of the sensory evaluation on certain commercially available crab and scallop flavourants are reported in Tables 7 and 8, respectively. The crab flavourants were grouped into those that were considered to be of good vs fair to poor quality. The strength, crab or scallop-likeness and presence of off-notes in the flavourants were reported. The Bibun products were also subjected to compositional analyses. The Bibun products are currently being formulated into the crab analogues being processed at Terra Nova Fisheries.

The odours of extracts dried in vacuo obtained from sampling at the various stages of the processing line for crab are reported in Table 9. A distinctive and unpleasant seawater odour was present in extracts of liquid samples where seawater was employed in the operation (ie. butchering water and in water used for dislodging meat from the shoulder shell cavities). The dried extract from the meat washed from the shoulder shells did not possess a crab-like odour and contained several off-notes. The leaching accentuated undesired attributes. The most desirable odours were present in the dried extracts from the cooker water, tip/leg shells, leg meat and tip meat. A comprehensive listing of the terms suggested by the sensory evaluation panelists for characterizing the odour of the crab is presented in Table 10.

SCALLOP FLAVOURED KAMABOKO

A scallop-flavoured kamaboko product was produced by incorporating 10% homogenized adductor muscles from scallops. The scallop analogue paste was texturized, cooked, chopped and then either breaded or tempura battered. The results of the sensory evaluation on four types of breadings and two types of tempura batters are listed in Table 11. Breading 8035 resulted in a product with a significantly greater overall acceptability compared to the other coatings ($P = \leq .05$). The tempura coated products were the least preferred. The judges praised the taste of the scallop analogues, although the texture of the product is softer than may be desirable.

EQUIPMENT

The pilot scale extrusion system that was developed for texturizing shellfish analogues prepared from kamaboko is shown in Fig. 2. The diameter of the extruder stream can be altered by changing the extruding die. The size of the fibers in the extruded stream can also be selected. Fig. 3 is a photograph of cooked and texturized shellfish kamaboko products. Of particular interest is the smooth surface skin which encloses the fiber core. The texture of the extruded kamaboko is also affected by the thermal processing protocol as well as by the extrusion aids that are blended into the kamaboko. The existing unit produces batches of either a crab or a scallop analogue every 20 minutes. A longer thermal tempering tunnel would permit the unit to operate continuously.

The system developed for washing and dewatering minced fish for producing surimi is shown in Fig. 4. The unit rotates a perforated stainless steel basket containing the minced fish at a low speed for washing, but for dewatering the rate of rotation is increased markedly. Two washing modes are available, ie. either by using the spray nozzles present in the interior of the basket or by filling the tank to immerse the basket. The unit is semiautomatic in that it can be operated by a timed control module.

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Fig. 1. **Concentration of solids in cooker water obtained from a continuous crab processing line.**

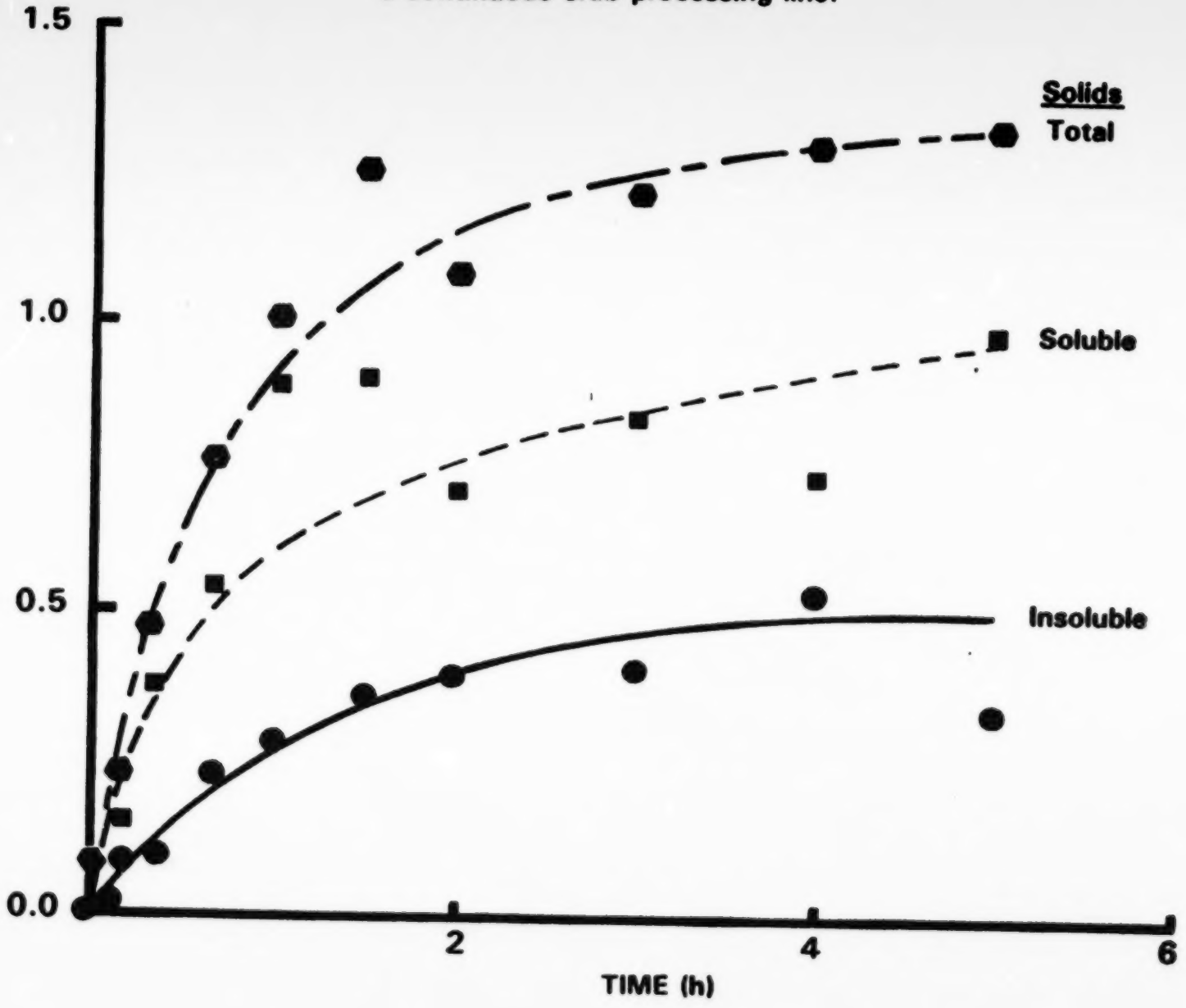

Fig. 2. Pilot scale extrusion system for texturizing surimi/kamaboko (left: extrusion unit, right: thermal unit).

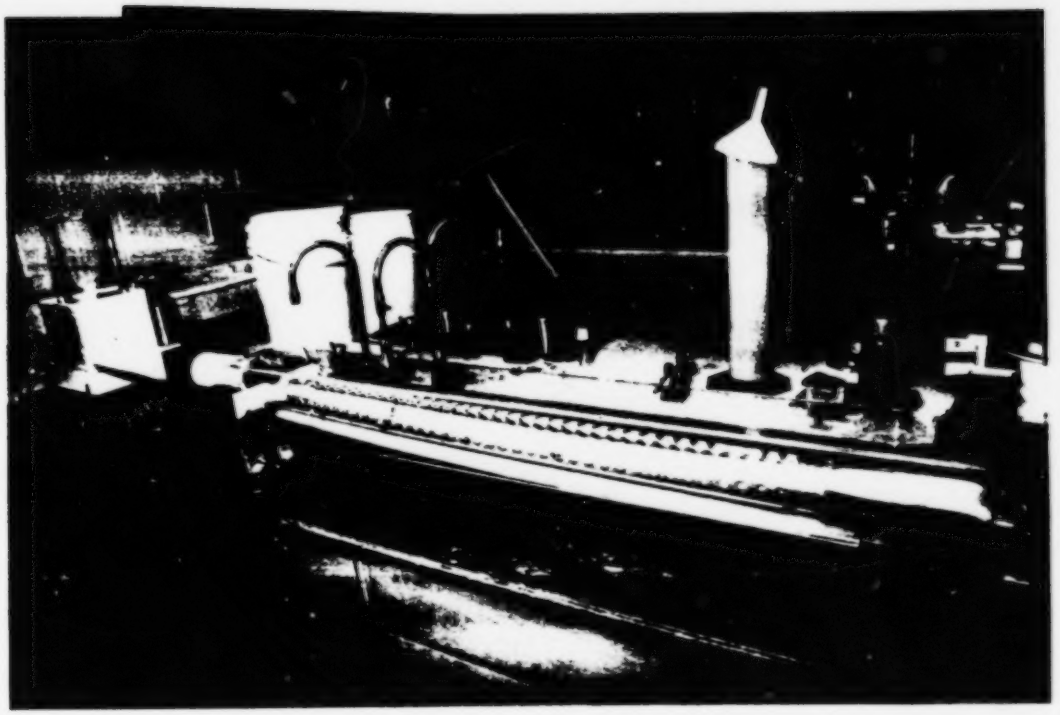

Fig. 3. Texturized surimi/kamaboko products.

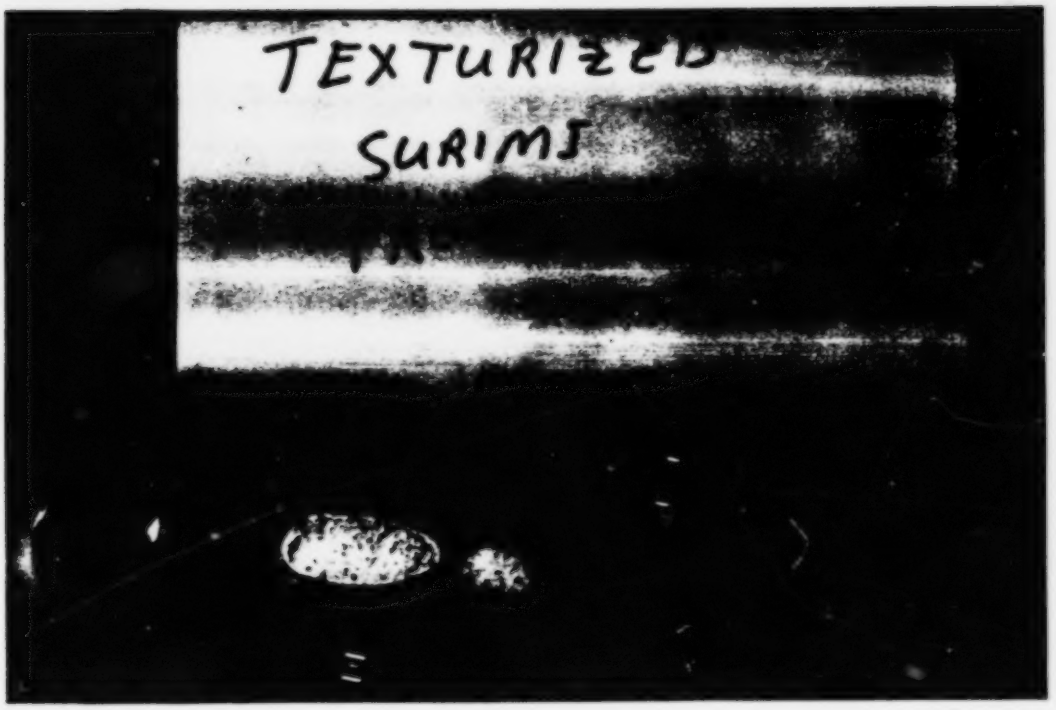

Fig. 4. System for washing and dewatering minced fish for the producing surimi (top: multiple speed drive system, bottom: perforated stainless steel basket that retains the minced fish).

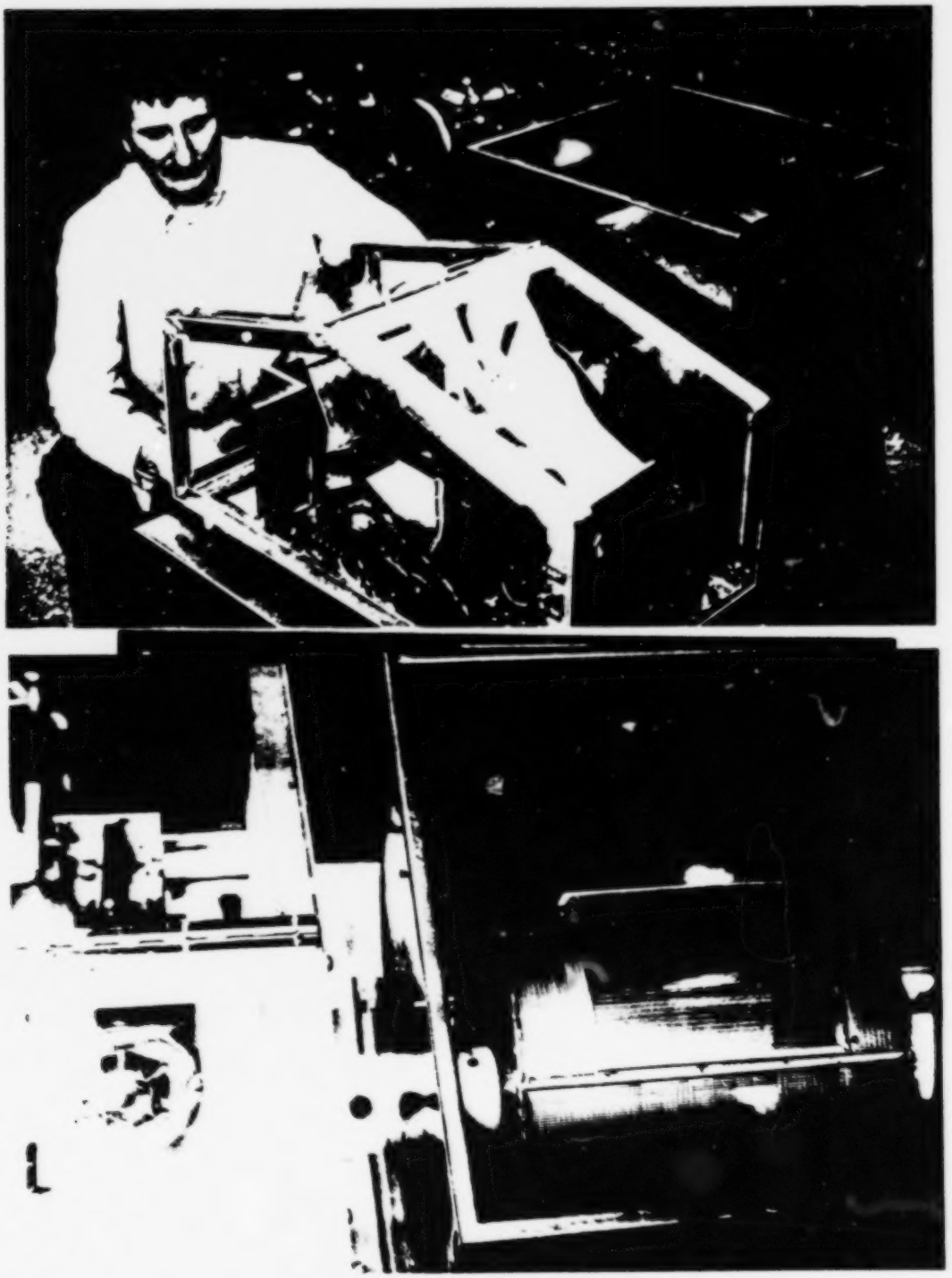

TABLE 1. CONTENTS OF IDENTIFIED TASTE-ACTIVE COMPONENTS IN SAMPLES OBTAINED FROM THE PROCESSING LINE FOR CRAB

	Subsamples from the line for the processing of crab[a]										
Component (Unites/g or mL)	Butchering water[b]	Cooker water	Cooler water	Shoulder water[b]	Leg water	Tip water	Shoulder shell[b]	Tip/leg shell	Leg meat	Tip meat	Shoulder meat[b]
Alanine (nmol)	94.5±140	3270±870	68.4±31	516±480	2130±1510	3910±1400	1370±560	2810±890	15200±4800	6920±4500	2210±930
Arginine (nmol)	93.2±140	3330±770	60.1±39	550±470	2580±1880	4160±1160	2100±550	3550±950	21700±5500	8590±4700	4410±1800
Glycine (nmol)	130±140	10100±2350	243±92	1750±1470	6520±4520	10200±2400	4580±1500	8570±2100	41200±16000	18500±12000	6310±2200
Glutamic acid (nmol)	12.8±24	353±110	3.30±4.7	69.2±76	166±120	377±110	126±40	310±94	926±260	552±350	174±100
Chloride (umol)	420±62	121±31	ND[c]	219±12	16.5±21	36.8±12	15.8±18	36.5±13	58.3±41	28.3±33	139±18
Phosphate (umol)	0.03±0.01	0.06±.03	0.06±0.02	0.05±0.02	0.42±0.14	0.06±0.36	0.15±0.08	0.15±0.03	13.6±4.0	3.43±2.2	0.47±0.07
Potassium (umol)	8.45±2.0	17.3±4.4	ND	4.90±0.42	6.00±5.0	10.2±2.0	4.95±3.6	13.6±2.70	37.6±26	16.7±12	7.33±0.47
Sodium (umol)	328±52	118±36	ND	204±18	16.3±15	28.5±7.4	19.5±15	46.2±7.7	45.0±33	32.5±24	116±28
Adenosine monophosphate (nmol)	<15.2	90.9±28	<15.2	<15.2	72.9	122	41.5	93.0±80	569±280	142	100
Inosine monophosphate (nmol) + Guanine monophosphate (nmol)	<5.77	45.3±8.1	<5.77	8.08	33.5	50.5	22.5	32.2±24	262±100	119	43.2

[a]Mean ± standard deviation of four values obtained from four separate sampling dates. If a standard deviation is not listed the samples were pooled prior to analysis.

[b]Seawater employed for the operation.

[c]Not detected at levels less than ca 0.1 nmol/mL or g.

TABLE 2. CONTENT OF SOLIDS IN SAMPLES OBTAINED FROM THE PROCESSING LINE FOR CRAB

Solids	Subsamples from the line for the processing of crab (% solids)[a]										
	Butchering water[b]	Cooker water	Cooler water	Shoulder water[b]	Leg water	Tip water	Shoulder shell[b]	Tip/leg shell	Leg meat	Tip meat	Shoulder meat[b]
Soluble	2.60±0.21	1.50±0.24	0.47±0.06	1.50±0.27	0.45±0.35	0.90±0.20	0.65±0.11	0.63±0.40	3.30±0.49	2.00±0.77	1.10±0.31
Insoluble	0.80±0.04	0.65±0.24	0.01±0.00	0.04±0.03	0.90±0.10	0.20±0.10	43.7±12.0	43.7±3.40	18.6±0.81	11.5±1.23	12.4±1.59
Total	2.68±0.25	2.15±0.48	0.06±0.06	1.54±0.30	0.54±0.45	0.54±0.45	44.3±3.80	43.3±3.80	19.9±1.30	13.5±2.00	13.5±1.90

[a]Mean ± standard deviation of four values obtained from four separate sampling dates.

[b]Seawater employed for the operation.

TABLE 3. CONTENT OF NUCLEOTIDES AND THEIR METABOLITES IN COMPONENTS OF COMMERCIAL CRAB FLAVOURS

Ingredients	Nucleotdes and metabolites (nmol/g)							
	Adenosine diphosphate	Adenosine monophosphate	Adenosine triphosphate	Guanine monophosphate	Hypoxanthine	Inosine	Inosine monophosphate	Uric acid
Crab extract (Bibun)	0.328	1.37	0.276	25.9	0.471	1.23	29.6	< 2.98
Crab extract NH (Bibun)	0.258	1.03	< 0.197	16.4	1.03	1.38	19.3	< 2.98
Crab flavour (Bibun)	0.220	0.820	0.168	ND[a]	0.471	< 0.746	ND	<1.19
AK crab flavour P	0.143	0.851	0.101	7.59	1.84	0.784	10.1	< 2.98
AK crab extract NH	< 0.468	0.577	<0.394	10.6	0.390	1.53	13.1	<2.98
Seasoning base BT	< 0.468	0.608	0.730	2.93	0.956	1.19	16.3	< 2.98

[a]Not detected at less than 0.1 nmol/g.

TABLE 4. CONTENT OF TASTE-ACTIVE COMPONENTS AND SOLIDS IN COMPONENTS OF COMMERCIAL CRAB FLAVOURS

Ingredients	Amino acids (nmol/g)				Ions (umol/g)				Nucleotides (nmol/g)		Solids (%)[a]
	Alanine	Arginine	Glycine	Glutamate	Chloride	Phosphate	Potassium	Sodium	Adenosine monophosphate	Guanine monophosphate	
Gelsin	ND[b]	ND	ND	ND	ND	ND	2210	1010	NDT[c]	NDT	89.2
Crab gold	ND	ND	ND	ND	ND	5.77	ND	ND	NDT	NDT	89.7
Fresh P	ND	ND	ND	ND	ND	51.9	ND	1180	NDT	NDT	91.5
Crab extract	170000	75200	5750000	1480000	4420	5.77	ND	5190	1.37	25.9	96.6
Wakesee starch	ND	ND	1900	1200	ND	ND	ND	ND	NDT	NDT	88.8
Pulren	ND	ND	3000	ND	ND	ND	260	ND	NDT	NDT	92.8
Guleeen	ND	ND	12200000	700	ND	ND	ND	ND	NDT	NDT	97.1
Aege	7000	ND	6800	12000	ND	ND	ND	ND	NDT	NDT	6.82
Silkpolly	ND	ND	ND	ND	ND	ND	ND	ND	NDT	NTD	63.9
Crab extract NH	6720	4690	124000	246000	3080	5.77	ND	2880	1.03	16.4	51.3
Crab flavour	879	404	1080	30300	ND	ND	ND	ND	0.820	NDT	47.7
Gel-Ace P	ND	ND	ND	ND	ND	0.96	ND	ND	NDT	NDT	98.6
AK crab flavour P	10400	1000	6200	871000	ND	3.85	ND	1250	0.851	7.59	89.5
AK crab extract NH	7000	4700	153000	359000	2400	5.77	ND	2120	0.577	10.6	59.5
Seasoning base BT	195000	48700	588000	3130000	2400	24.0	57.7	4130	< 0.608	2.93	77.9

[a]Total.

[b]Not detected at levels less than ca 0.1 nmol/ml or g.

[c]Not determined.

TABLE 5. CONTENTS OF SELECTED TASTE-ACTIVE COMPOUNDS IN ICELANDIC SCALLOPS

Compound (Units/mL or g)	Subsamples of butchered scallops[a]	
	Adductor muscle	Viscera and mantle
Alanine (nmol	5310±1110	6950±1160
Arginine (nmol)	4980±2570	7710±2230
Glycine (nmol)	78600±24800	79800±22300
Glutamic acid (nmol)	2370±2200	2960±915
Chloride (umol)	33.0±0.0	204±12
Phosphate (umol)	12.9±4.3	5.45±1.7
Potassium (umol)	50.0±0.0	42.0±4.0
Sodium (umol)	37.7±7.7	222±11
Adenosine monophosphate (nmol)	236±290	<50.6±0.0
Inosine monophosphate (nmol) + Guanine monophosphate (nmol)	92.1±61	69.1±5.3

[a]Mean ± standard deviation of three values representing three separate extractions from the same collection lot of scallops.

TABLE 6. CONTENTS OF SOLIDS IN BUTCHERED ICELANDIC SCALLOPS

Solids	Subsamples of butchered scallops (% solids)[a]	
	Adductor muscle	Viscera and mantle
Soluble	1.47±0.12	1.90±0.87
Insoluble	17.4±0.10	12.3±1.14
Total	18.9±0.21	14.2±1.86

[a]Mean ± standard deviation of three values representing three separate extractions from the same collection lot of scallops.

TABLE 7. SENSORY EVALUATION OF COMMERCIALLY AVAILABLE CRAB FLAVOURANTS

Quality/Product	Supplier	Comments
Good quality:		
Crab extract powder (1300)	Nikken Food	Crab-like, needs to be enhanced
Natural and artificial crab flavour powder (EP-14835)	Norda	Crab-like lingering note, artificial note
Natural crab flavour (71-06779)	Naarden	Crab-like
Natural and artificial crabmeat flavour (NAF-2773)	T. Hasegawa	Crab-like aroma and taste
Crab flavour	Bibun	Crab-like, clean
Crab extract	Bibun	Crab-like, medicinal, no ammonia
Ak crab flavour P powder	Bibun	Crab-like, lingering, no ammonia
Fair to poor quality:		
Crab flavour extract powder (3700)	Intek	Brothy, slightly fishy, fair crab flavour
Taste of crab (R6388)	Haarman & Reimer	Mild fishy note, weak crab flavour
Natural and artificial crabmeat flavour (NAF-2774)	T. Hasegawa	Very weak flavour
Crab flavour extract powder (3700)	Intek	Slightly fishy, whole crab flavour, brothy
Ak crab extract	Bibun	Not crab-like, medicinal, brothy no ammonia
Seasoning base BT	Bibun	Bouillon, spicey, sweet, MSG, salty, not crab-like

TABLE 8. SENSORY EVALUATION OF COMMERCIALLY AVAILABLE SCALLOP FLAVOURANTS

Product	Supplier	Comments
Natural and artificial scallop flavour (TH 620)	T. Hasegawa	Scallop-like, slightly acidic, bitter and astringent aftertaste.
Scallop flavour extract powder 3500	Intek	Reacted HVP-like taste, slightly more fishy than Kikkoman product
Scallop extract 5650	Kikkoman	Reacted HVP-like flavour note

TABLE 9. EVALUATION OF ODOUR OF VACUUM DRIED RESIDUES OF EXTRACTS OBTAINED FROM THE PROCESSING LINE FOR CRAB

Sample	Comments[a]
Liquids:	
Butchering[b]	Fishy, seawater, unpleasant, not crab-like
Cooker	Crab-like, ammonia
Cooler	Tobacco, cow-barn-like
Shoulder[b]	Fishy, seawater, sharky, not crab-like
Shells:	
Tip, leg	Crab-like, ammonia
Shoulder[b]	Mild, ammonia, dried fish, not pleasant, crab-like
Meats:	
Leg	Clean, crab-like
Tip	Mild, clean, crab-like
Shoulder[b]	Cod liver oil-like, hay-like, not crab-like

[a]Results from six experienced panelists.
[b]Seawater employed.

TABLE 10. DESCRIPTION TERMS FOR RANKING QUALITY AND STRENGTH OF ODOUR OF CRAB FLAVOURANTS

Flavour note	Flavour note
ammonia	intence (not)
aromatic	lingering
astringent	medicinal
beef extract-like	MSG-like
bitter	minty
boullion-like	musty
briney	oniony
brothy	pleasant (not)
burnt	poor
clean	
cod liver oil-like	putrid
cow barn-like	rancid
crab-like (not)	reacted sugar
dried fish-like	roasted
dried shrimp-like	seawater-like
dried squid-like	seaweedy
fishy	sharky
good	spicy
green vegetable-like	sweet
hay-like	tobacco-like
HVP-like	yeasty

TABLE 11. RESULTS OF ANALYSIS OF VARIANCE ON THE PREFERENCE TESTING BY HEDONIC SCALE EVALUATION OF THE SENSORY CHARACTERISTICS OF BREADED AND TEMPURA BATTERED SCALLOP FLAVOURED AND TEXTURIZED SURIMI

	Hedonic score[a]			
Breading system[b]	Colour	Flavour	Texture[c]	Acceptability
Breading 8035	8.3±0.5a	7.7±0.5a	7	8.2±0.4a
Breading 7697	7.7±1.5ab	6.2±1.5c	5	7.2±1.6
Breading 8048	7.0±1.4c	7.7±0.5a	6	7.2±0.8b
Breading 8025	7.3±0.8bc	7.3±0.8a	7	7.3±0.5b
Tempura 4582	6.2±2.1d	6.7±1.2b	5	5.2±2.1c
Tempura 4584	6.8±2.5cd	5.8±1.6c	5	5.8±2.0c

[a]Samples were rated using a nine-point Hedonic scale in which 9=excellent and 1=extremely poor; means ± standard deviations are the results of 6 replicates; means followed by the same letter are not significantly different at $P \leq 0.05$, n=36, df=5.25 (P=Probability) (dF=Degrees of Freedom).

[b]Breading systems are defined in the materials and methods section.

[c]One panelist.

APPENDIX

APP. TABLE 1. CONTENTS OF FREE-AMINO ACIDS IN SAMPLES OBTAINED FROM THE PROCESSING LINE FOR CRAB

Component (Unites/g or mL)	Subsamples from the line for the processing of crab[a]										
	Butchering water[b]	Cooker water	Cooler water	Shoulder water[b]	Leg water	Tip water	Shoulder shell[b]	Tip/leg shell	Leg meat	Tip meat	Shoulder meat[b]
Alanine	94.5±140	327±870	68.4±31	516±480	2130±1500	3910±1400	1370±560	2810±890	15200±4800	6920±4500	2210±920
α-Aminoadipic acid	ND[c]	48.8±9.8	ND	ND	17.0±16	19.0±8.4	ND	7.50±15	58.2±61	16.7±19	8.33±17
α-Amino-n-butyric acid	ND	34.7±20	ND	1.00±2.00	12.2±19	22.8±22	ND	5.85±27	32.3±27	3.33±6.7	ND
Arginine	93.2±140	3330±770	60.1±39	550±470	2580±1900	4160±1200	2100±550	3550±950	21700±5500	8590±4700	4410±1800
Asparegine	5.00±10	37.3±8.3	0.525±1.1	5.50±10	13.1±16	11.9±16	24.5±32	23.9±31	461±55	89.7±62	17.7±15
Aspartic acid	8.25±16	240±63	1.25±1.9	52.0±54	89.5±66	193±89	72.4±17	179±58	540±130	339±210	85.1±35
Citruline	ND	16.0±8.1	ND	1.00±2.0	3.98±8.0	15.0±10	ND	5.21±7.1	16.7±19	ND	ND
Cystathione	0.50±1.0	15.2±12	ND	0.275±0.48	6.25±9.5	6.20±3.5	1.20±1.5	5.45±6.2	24.1±16	11.7±11	ND
Cysteic acid	0.625±1.3	37.3±8.3	0.525±1.1	5.00±1.0	13.1±16	11.9±16	50.4±11	11.4±23	13.5±27	9.58±19	6.33±13
Cystine	2.53±4.4	41.7±18	0.200±0.40	3.53±4.0	42.5±30	12.7±4.9	5.25±2.6	3.71±3.8	60.6±51	13.7±23	0.083±0.17
r-Aminobutyric acid	ND	34.7±20	ND	1.00±2.0	12.2±19	22.8±23	ND	ND	24.2±16	14.4±14	8.33±17
Glutamic acid	12.8±24	353±110	3.30±4.7	69.2±76	166±120	337±110	126±40	310±94	926±260	552±350	174±100
Glutamine	12.5±24	57.4±24	0.450±0.90	19.1±12	93.8±71	197±80	83.1±53	129±66	872±290	332±230	161±86
Glycine	130±140	1010±2400	243±92	1750±1500	6520±4500	10200±2400	4580±1500	8570±2100	41200±16000	18500±12000	6310±2200
Histidine	27.5±50	220±62	5.33±5.4	157±300	106±80	167±63	126±49	201±95	608±240	378±280	176±140
Isoleucine	36.1±57	1770±490	15.0±4.4	192±310	480±44	915±410	337±130	684±370	1410±730	918±500	217±100
Leucine	74.6±120	2010±510	17.4±5.3	209±340	514±410	977±530	390±140	754±420	1620±860	1000±460	264±120
L-methylhistidine	ND	262±460	ND	ND	9.00±11	16.6±13	ND	0.675±1.4	13.6±27	3.00±6.0	6.65±13
Lysine	78.4±120	1110±750	10.6±1.2	174±220	319±250	555±290	324±120	543±250	1060±470	726±340	255±93
Methionine	29.5±45	1180±260	6.10±2.9	124±210	332±280	618±260	274±98	502±240	1010±470	703±380	222±39
3-methylhistidine	ND	7.25±4.9	ND	2.50±5.0	3.90±6.5	28.7±38	15.2±3.9	42.2±24	197±160	153±110	8.33±17
Ornithine	0.500±1.0	44.8±12	0.200±0.40	1.30±2.5	26.7±26	26.3±13	11.5±8.0	46.2±24	89.3±43	27.6±27	36.1±39
Phenylalanine	40.0±70	1290±300	7.63±3.5	139±220	367±350	590±250	294±100	599±290	906±400	716±320	181±77
Proline	20.0±40	1390±350	13.9±19	219±140	1230±860	2080±830	543±240	1230±300	14400±3900	3730±2700	1390±140
Sarcosine	190±360	4800±1000	3.30±6.6	432±830	1390±240	2670±960	1140±630	2830±1300	4760±1100	3420±2400	354±170
Serine	27.0±50	582±200	3.73±6.2	125±120	265±180	459±150	222±52	413±140	1950±590	955±650	293±150
Taurine	104±140	3860±960	21.0±20	265±140	2540±1900	4670±1500	1780±800	3760±1300	15100±2900	8590±4900	2630±1000
Threonine	18.6±34	333±110	3.50±4.4	55.6±60	130±130	231±96	81±20	128±36	830±270	211±210	119±48
Tryptophan	8.50±16	354±79	3.63±4.8	33.0±58	70.8±72	117±63	101±52	159±64	150±93	202±120	51.3±21
Tyrosine	23.6±47	951±220	7.05±2.5	95.0±160	252±220	395±180	219±68	409±160	631±270	494±160	187±89
Valine	39.6±71	1830±430	9.08±6.7	190±310	442±420	896±370	396±140	696±370	1430±740	1010±570	217±140

[a]Mean ± standard deviation of four values obtained from four separate sampling dates.
[b]Seawater employed for the operation.
[c]Not detectable at levels less than ca 0.1 nmol/mL or g.

APP. TABLE 2. CONTENT OF NUCLEOTIDES AND THEIR METABOLITES IN SAMPLES OBTAINED FROM THE PROCESSING LINE FOR CRAB

Nucleotide or metabolite (nmol/mL or g)	Subsamples from the line for the processing of crab[a]										
	Butchering water[b]	Cooker water	Cooler water	Shoulder water[b]	Leg water	Tip water	Shoulder shell[b]	Tip/leg shell	Leg meat	Tip meat	Shoulder meat[b]
Adenosine diphosphate	11.7	70.0±21	0.936	6.32	111	144	70.2	57.9±63	462±500	177	150
Adenosine monophosphate	15.2	90.9±28	<15.2	<15.2	72.9	122	41.5	93.0±80	569±280	142	100
Adenosine triphosphate	19.7	<19.7±0.0	<19.7	<19.7	<19.7	<19.7	<29.6	<29.6±0.0	<115±42	<65.7	<32.8
Hypoxanthine	2.20	61.5±15	5.14	5.88	21.3	9.55	37.5	27.6±5.2	19.0±15	17.1	26.9
Inosine	3.73	41.7±9.9	<7.46	3.36	30.6	22.0	21.3	35.8±26	85.4±63	47.2	55.9
Inosine monophosphate + Guanine monophospate	<5.77	45.3±8.1	<5.77	8.08	33.5	50.5	22.5	32.2±24	262±100	119	43.2
Uric acid	12.5	196±66	<11.9	10.1	27.4	<29.7	79.4	70.4±41	193±71	99.0	79.2

[a]Mean ± standard deviation of four values obtained from four separate sampling dates.

[b]Seawater employed for the operation.

APP. TABLE 3. CONTENT OF FREE-AMINO ACIDS IN COMPONENTS OF COMMERCIAL CRAB FLAVOURS

Amino acids	Components of commercial crab flavours[a]							
	Crab extract	Gulesen	Asge[b] extract NH	Crab[b] flavour	Crab[b] flavour	Ak Crab flavour P	AK Crab extract	Seasoning base BT
Alanine	170000	ND[a]	7000	6720	879	10400	7000	195000
a-Aminodipic acid	ND	ND	ND	ND	ND	ND	ND	ND
a-Aminobutyric acid	ND	ND	ND	64.1	47.7	3550	ND	ND
Arginine	75200	ND	ND	4690	404	1000	4700	48700
Asparagine	ND	ND	ND	ND	ND	ND	ND	ND
Aspartic acid	86600	ND	14500	757	186	3500	1400	92700
Citrulline	ND	ND	ND	ND	38.7	ND	ND	ND
Cystathione	30	ND	ND	5.70	1.0	ND	ND	ND
Cysteic acid	ND	ND	ND	1690	27.7	7100	3800	1700
Cystine	500	ND	ND	89.2	62.0	1000	ND	1000
r-Aminobutyric acid	500	ND	ND	106	21.0	10500	ND	ND
Glutamic acid	1480000	700	12000	246000	30300	871000	359000	3130000
Glutamine	ND	ND	ND	394	5150.0	52100	ND	ND
Glycine	5750000	12200000	6800	124000	1080	6200	153000	588000
Histidine	9900	ND	Nd	162	8060	1000	ND	13600
Isoleucine	16100	600	2000	1510	201	7100	1350	16800
Leucine	35000	ND	4000	1970	439	7500	1850	38500
L-methylhistidine	ND	ND	ND	ND	ND	ND	ND	ND
Lysine	46000	ND	ND	1570	374	1150	1600	44900
Methionine	9600	300	15800	313	1270	15000	ND	9650
3-Methylhistidine	ND	ND	ND	6.8	ND	ND	ND	ND
Ornithine	800	ND	ND	310	235	100	ND	100
Phenylalanine	11800	ND	ND	1050	183	500	1000	15500
Proline	101000	ND	ND	1060	284	2500	2500	101000
Sarcosine	ND	ND	ND	2560	ND	ND	ND	ND
Serine	66100	200	12000	769	226	5600	1000	51200
Taurine	700	ND	ND	4030	811	1000	4750	3800
Threonine	34100	ND	2000	707	199	1200	2000	35600
Tryptophan	ND	ND	ND	ND	21	500	500	ND
Tyrosine	2100	ND	ND	499	128	2200	500	2000
Valine	32500	ND	ND	1820	326	6500	ND	37500

[a]Not detectable at levels less than ca 0.1 nmol/mL or g. Free-amino acids were not detected in Gelmin, Crab gold, Fresh P, Silkpolly, Wakesee starch, Pulran or Gelace P.

[b]Results are in units of nmol/mL.

APP. TABLE 4. CONTENTS OF FREE-AMINO ACIDS IN BUTCHERED ICELANDIC SCALLOPS

Amino acids[b] (nmol/mL)	Subsamples of butchered scallops[a]	
	Adductor muscle	Viscera and mantle
Alanine	5310±1110	6950±1160
a-Aminoadipic acid	36.6±32.8	17.8±30.8
Arginine	4980±2570	7710±2230
Asparagine	540±418	349±464
Aspartic acid	1160±1100	637±443
Citrulline	228±322	58.8±64.8
Cystathione	11.6±9.25	3.67±6.35
Cysteic acid	188±102	156±105
Cystine	62.8±58.9	51.7±89.5
Glutamic acid	2370±2200	2960±915
Glutamine	399±530	554±736
Glycine	78600±24800	79800±22300
Histidine	501±418	364±375
Isoleucine	1050±784	790±789
Leucine	1620±1320	1230±1450
Lysine	762±769	866±955
Methionine	776±500	485±624
3-methylhistidine	16.7±28.9	52.7±91.2
Ornithine	585±794	59.4±91.4
Phenylalanine	840±662	628±872
Proline	1270±921	394±510
Serine	766±688	1090±1150
Taurine	20000±1470	31200±10500
Threonine	1650±1480	980±991
Tryptophan	129±158	211±310
Tyrosine	465±369	582±698
Valine	1350±988	880±1160

[a]Mean ± standard deviation of three values representing three separate extractions from the same collection lot of scallops.

[b]The following free-amino acids were not detected at levels less than ca 0.1 nmol/g: a - amino-n-butyric acid, L-methylhistidine and sarcosine.

APP. TABLE 5. CONTENTS OF NUCLEOTIDES AND THEIR METABOLITES IN BUTCHERED ICELANDIC SCALLOPS

Nucleotide or metabolite (nmol/mL or g)	Subsamples of butchered scallops[a]	
	Adductor muscle	Viscera and mantle
Adenosine diphosphate	77.3±54	26.8±18
Adenosine monophosphate	236±290	50.6±0.0
Adenosine triphosphate	<54.7±19	<32.8±0.0
Hypoxanthine	2230±1100	1380±520
Inosine	1090±430	656±140
Inosine monophosphate + guanine monophospate	92.1±61	69.1±53
Uric acid	144±160	184±100

[a]Mean ± standard deviation of three values representing three separate extractions from the same collection lot of scallops.

APP. TABLE 6. THE CONTENT OF SOLIDS (%; TOTAL, INSOLUBLE AND SOLUBLE) IN COOKER LIQUOR OBTAINED FROM A CRAB PROCESSING LINE BASED ON COLLECTION MADE OVER TIMED INTERVALS

	Solids (%)[a]		
Time (h)	Total	Insoluble[a]	Soluble
0.00	0.09±0.04	0.01±0.01	0.08±0.04
0.08	0.09±0.06	0.02±0.01	0.08±0.05
0.17	0.23±0.14	0.09±0.07	0.14±0.07
0.33	0.47±0.09	0.10±0.06	0.37±0.06
0.67	0.76±0.02	0.22±0.21	0.54±0.21
1.00	1.17±0.13	0.28±0.12	0.89±0.03
1.50	1.26±0.53	0.36±0.21	0.90±0.34
2.00	1.09±0.51	0.39±0.10	0.70±0.43
3.00	1.23±0.75	0.40±0.32	0.83±0.43
4.00	131±0.43	0.54±0.13	0.73±0.31
5.00	1.34±0.23	0.35±0.05	0.99±0.20

[a]Values are means ± standard deviations of samples taken in triplicate.